Aalto University
School of Engineering

Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)

Master's Thesis
Department of Real Estate, Planning and Geoinformatics,
School of Engineering, Aalto University

Espoo, 08 October 2013

Bachelor of Science in Technology
Elisabeth Pietarila

Supervisor: Professor Seppo Junnila
Instructor: M.Sc Ville Reinikainen

Aalto University
School of Engineering

Aalto University,
P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Elisabeth Pietarila

Title of thesis Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)

Degree programme Energy and HVAC-Technology

Major/minor Real Estate Management **Code of professorship** Maa-20

Thesis supervisor Professor Seppo Junnila

Thesis advisor(s) M.Sc. Ville Reinikainen

Date 08.10.2013 **Number of pages** 95+20 **Language** English

Facing global climate change, the world must transfer to a sustainable energy system where energy should be used more efficiently. Built environment makes an important contribution to improving energy efficiency, because buildings account for 40 % of the world's energy consumption. In particular, the existing buildings have a significant role in improving energy efficiency because the building stock is renewed slowly.

The objective of this study is to investigate which services a light BIM (building information model) enables for improving the energy performance of existing office buildings. In particular, the services that are useful for office tenants are considered. The objective of the study is explored by a literature review and an empirical study which consists both of a case study, including the interviews of tenants and energy simulations, and a questionnaire study. In this study, a light BIM refers to a BIM that only consists of required information in adequate accuracy to investigate the energy performance of a building. The light BIM can be created by two different methods. It is either modelled based on a building's architectural drawing or it is created from an existing 2D space model, in which case the modelling work is reduced.

The results of this study prove that a light BIM enables various energy performance services for existing office buildings. In particular, the light BIM can be utilised in creating Energy Performance Certificates and a base of Green Lease model, in investigating the effect of the behavioural change of tenants on energy efficiency and in investigating the indoor air quality. The light BIM makes possible to investigate the distribution of energy consumption between different tenants in multitenant buildings and to set viable energy efficiency goals for individual tenants. However, regular energy consumption measuring is required to guarantee the realisation of the given energy efficiency goals and the verification of the realised cost distribution between the owner and tenant in Green Leases.

The available light BIM of the case building reduced the work substantially. To estimate the real amount of the work of creating a light BIM requires more research on information exchange opportunities between a space management application and an energy simulation application. Further study could be carried out to compare the energy calculation results of a case in which some of the initial values of the model are estimated values to a case where the exact values are used. Moreover, there should be research about how existing BIM models devised for different purposes can be utilised better and in a wider variety of uses.

Keywords Energy Performance, Building Information Model (BIM), Office Building, Energy Performance Certificate, Green Lease, Building Energy Simulation

Aalto-yliopisto
Insinööritieteiden korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi

Diplomityön tiivistelmä

Tekijä Elisabeth Pietarila

Työn nimi Toimistorakennusten energiatehokkuuden parantaminen kevyen tietomallinnuksen avulla

Koulutusohjelma Energia- ja LVI-tekniikka

Pää-/sivuaine Kiinteistöjohtaminen **Professuurikoodi** Maa-20

Työn valvoja Professori Seppo Junnila

Työn ohjaaja(t) Diplomi-insinööri Ville Reinikainen

Päivämäärä 08.10.2013 **Sivumäärä** 95+20 **Kieli** Englanti

Ilmastonmuutoksen etenemisen estämiseksi maapallon täytyy siirtyä kestävämpään energiajärjestelmään, jossa energiaa tulee käyttää entistä tehokkaammin. Rakennetulla ympäristöllä on merkittävä osuus energiatehokkuuden parantamisessa, koska rakennusten osuus on 40 % maapallon energiankulutuksesta. Koska rakennuskanta uusiutuu hitaasti, erityisesti vanhojen rakennusten energiatehokkuuden parantamisella on keskeinen rooli.

Tämän tutkimuksen tavoitteena oli tutkia millaisia palveluita kevyt tietomalli mahdollistaa olemassa olevien toimistorakennusten energiatehokkuuden parantamiseen. Erityisesti vuokralaisille hyödyllisiä palveluita tarkasteltiin. Tutkimuksen tavoitteeseen vastattiin kirjallisuuskatsauksella ja empiirisellä tutkimuksella, joka koostui tapaustutkimuksesta ja kyselytutkimuksesta. Tapaustutkimus koostui vuokralaisten haastatteluista ja tapausrakennuksen energiasimuloinneista.

Tässä tutkimuksessa, kevyellä tietomallilla tarkoittaa tietomallia, joka sisältää vain vaaditun tiedon riittävällä tarkkuudella tutkia rakennuksen energiatehokkuutta. Kevyt tietomalli voidaan luoda kahdella eri tavalla; joko mallintaa perustuen rakennuksen arkkitehtipiirustukseen tai luoda olemassa olevasta kaksiulotteisesta tilamallista, jolloin mallinnus työ vähenee. Tutkimuksen tulokset osoittivat, että kevyt tietomalli mahdollistaa useita erilaisia energiatehokkuuspalveluja olemassa oleville toimistorakennuksille. Sitä voidaan hyödyntää etenkin rakennuksen energiatodistuksen laatimisessa ja Green Lease vuokrasopimusmallin perustan luomisessa sekä tutkimaan vuokralaisten käyttäytymisen vaikutuksia energiatehokkuuteen että sisäilmanlaadun tutkimiseen. Kevyen tietomallin avulla voidaan tutkia monivuokralaisrakennuksen energiakulutuksen (sähkö, lämpö, vesi) jakautumista ja asettaa vuokralaisille energiatehokkuustavoitteet. Kulutusmittarointia vaaditaan kuitenkin varmistamaan energiatehokkuustavoitteiden toteutuminen ja toteutuneiden kustannusten jakautuminen omistajan ja vuokralaisen välillä Green Lease sopimuksissa.

Tässä tutkimuksessa tapausrakennuksen olemassa oleva kevyt tietomalli vähensi työtä merkittävästi. Kevyen tietomallin luomisen todellisen työmäärän arviointi vaatii lisätutkimusta tiedonsiirtomahdollisuuksista tilanhallintaohjelman ja energiasimulointiohjelman välillä. Lisätutkimusta voitaisiin suorittaa myös vertailemaan energialaskentatuloksia tapauksessa, jossa osa mallin lähtöarvoista on arvioitu, tapaukseen, jossa on käytetty tarkkoja arvoja. Lisäksi enemmän tutkimusta tarvittaisiin siitä, miten eri tarkoituksiin tehtyjä tietomalleja voitaisiin hyödyntää paremmin ja useampiin eri tarkoituksiin.

Avainsanat energiatehokkuus, rakennuksen tietomalli (BIM), toimistorakennus, energiatodistus, vihreä vuokrasopimus, energiasimulointi

Acknowledgements

This Master Thesis was part of the NewWOw (New Ways of Working) work package of the PRE-program and was carried out between March and September 2013 at Granlund Oy. The PRE-program is the research program of RYM Oy with 43 participants, 37 companies and 6 research institutes.

As a supervisor of the thesis was Seppo Junnila a professor of Real Estate Business at Aalto University and as an instructor was Ville Reinikainen, a Master of Science and a Department Director of Energy and Environment at Granlund Oy. I sincerely thank Seppo Junnila for all the advice and comments throughout this project. I would like to thank Ville Reinikainen for comments and especially for the discussions that helped me progress in my study.

I would like to give special thanks to the experts of different areas at Granlund Oy: D.Sc Heikki Ihasalo, D.Sc Heikki Lonka and a group manager of Energy Consulting, Kristian Bäckström, for their professional comments and support. I would like to thank Kai Patja, a Business Unit Director of Rapal Oy, for cooperation and help with the questionnaire study.

I would like to thank Senate Properties, especially Pasi Hyyppä, who enabled the realisation of the interview study. Moreover, I am grateful for all the participants in the interviews and in the online survey and for the other people who were somehow involved in this study. Thanks go also to my workmates at Granlund who helped me to forget the Thesis every so often and maintain the work motivation.

My heartfelt thanks go especially to my friend Tytti for her comments and support during this project. In addition, I would like to thank my family and dear friends for all the support. Now when the graduation is near, I want to give thanks to all the new friends from studying time in Otaniemi for being part of memorable experiences during this period. Above all, I would like to thank my boyfriend Joonas for being my support during these years.

Espoo, 08 October 2013

Elisabeth Pietarila

Table of Contents

List of Abbreviations

BIM	Building information model
BREEAM	BRE Environmental Assessment Method
CAD	Computer-aided design
COBIM	Common BIM Requirement
EEA	European Environment Agency
EPBD	Energy Performance of Buildings directive
EPC	Energy performance certificate
FiSIAQ	Finnish Association of HVAC Societies
gbXML	Open Green Building XML Schema
GUI	Graphical user interface
GSA	U.S. General Services Administration
g-value	Total solar transmittance
HVAC	Heating ventilation and air conditioning
HCFC	Hydrochlorofluorocarbon
IAI	International Alliance for Interoperability
IFC	Industry Foundation Classes
IfcXML	IFC Model using XML schema language
IT	Information technology
KTI	Kiinteistötieto, Property Information
LEED	Leadership in Energy & Environmental Design
MEP	Mechanical, electrical and plumbing
NBCF	National Building Code of Finland
NewWow	New ways of working package
PRE	Built Environment Process Re-engineering
XML	Extensible Markup Language

1 INTRODUCTION

1.1 Background

Facing global climate change, the world must transfer to a sustainable energy system as well as manage energy demand and supply better (Solomon & Krishna, 2011). The significant problem is that sustainable development and energy sector face major challenges due to the constantly growing energy consumption caused by the population growth and the rising standards of living (Kuula, 2011). To decrease energy consumption and greenhouse gas emissions, energy should be used more efficiently (Ministry of the Environment, 2011).

Built environment makes an important contribution to improving energy efficiency, because buildings account for 30 % to 40 % of the world's energy consumption and are responsible for 25 % to 35 % of the world's greenhouse gas emissions (UNDP, 2009). In buildings, energy efficiency refers to satisfying the needs of a building and its users with a smaller amount of conventional energy (Railio, 2011). Existing building stock has an important role in reducing energy consumption because the building stock is renewed slowly, for example in Finland the new construction is just one per cent of the annual building stock. (Saari, et al., 2010; Tekes, 2012).

The importance of energy efficiency has increased among the objectives of real estate companies and environmental aspects are taking a central stage to real estate business management (Kaleva, et al., 2011). According to the results of the Working Environment barometer of KTI (2012) energy efficiency has increased to be a third important selection criterion of buildings and services. In addition, 35 % of the respondents of the survey chose the energy efficiency to be the most important factor relative to sustainable development. Improving energy efficiency enables significant cost savings and reduced emissions but also to better comfort and working environment, more satisfied users and even better productivity (Haji-Sapar & Eang Lee, 2005).

The key role in improving energy efficiency in the existing building stock is played by the owners and users of buildings. The owners are responsible for the technical and operational features of a building and typically also for maintenance including heating. (Kaleva, et al., 2011). The attitude of property users to environmental responsibility and energy efficiency measures cannot be underestimated because they represent the top of the value chain in the real estate and construction sector. (Lehtonen, et al., 2007). The users are responsible for space efficiency, energy management for the users' operation, water consumption and the amount of waste. (Kaleva, et al., 2011). On the basis of their level of rents, both investment decisions are made and the building life cycle services are funded. Moreover, user behaviour can directly affect half of the electricity use of a property. The challenge is to encourage the users of properties into energy saving actions. (Lehtonen, et al., 2007).

In Finland, tenants have traditionally paid gross rent for an owner; in that case the owner has taken care of all the maintenance and operation costs. If the cost of the contents of the rent is more visible, it will increase the understanding about the economic benefits resulting from energy savings. (Lehtonen, et al., 2007). In so-called Green Leases the owner and tenant are directed by financial incentives to utilise environmentally friendly solutions. To investigate the energy efficient and environmentally friendly methods, usually requires metering (Senate Properties, 2012) that is experienced to be expensive and difficult in compared with the gained benefit (Kuula, 2012).

The commitment of the European Union member states on improving energy efficiency leads to new demands in the building sector in the form of tightened regulations. In the summer of 2010, the European Parliament adopted the recast directive (2010/31/EU) to improve the energy performance of buildings (EPBD). (Vehviläinen & Pesola, 2010). In Finland, the directive impacts particularly on the form of changing building regulations. The major change is a transition in calculating the annual energy performance of a building, the so called E-value, when traditionally mainly individual structures and building solutions have been regulated (Railio, 2011). In addition, Energy Performance Certificates (EPCs) based on the calculated E-value (Decree on EPC, 2013) and the minimum energy performance requirements in renovations are gradually entering into force in all the type of buildings (Decree on Improving Energy Performance in Renovations, 2013/4).

Along with tightened requirements for design, developed tools and research activities, the discussion about building information modelling (BIM) has increased (Penttilä, 2009). The building information modelling refers to the 3D design of buildings, so that necessary information needed in a building project is stored in a data model by using parametric objects. BIM models can be utilised during the whole life cycle of a building in different ways, such as in supporting investment decisions, in buildability, in energy and environment analyses and demonstrating design. (Järvinen & Laine, 2012).

BIM applications are already available and developed into real estate management for example for facility management, space management and maintenance management. (Järvinen & Laine, 2012). According to the survey of Finnish Building Information Group (2013), already 65 % of the respondents who are working in the building trade, use BIM in their work. When is a question of existing buildings, BIM is however, often experienced to be too heavy because of extra work and cost which is caused. However, a simplified and lighter BIM could be realised with a small effort in a short time if it is concentrated on producing just the essential information that is needed to take a good use of the model. (Kaukonen, 2012). The light BIM of an existing building could be utilized improving energy performance and offering new type of services for owners and tenants. In order to obtain the full benefit of BIM in improving the energy performance of existing buildings, new services and business models are needed.

1.2 Research Objective and Outline

The main objective of this thesis is to investigate which services a light Building Information Model (BIM) enables for improving the energy performance of existing office buildings.

The next questions were leading the research:

1. How the energy performance of buildings is defined and where is it based on?
2. In which way can the energy performance of existing office buildings be improved?
3. What is BIM and how is it utilised improving the energy performance of buildings?
4. How can the light BIM of an existing office building be utilised improving energy performance?
5. What sort of energy efficiency services enabled by a light BIM, the tenants of office buildings would be interested?

This study was outlined to relate to existing office buildings; other building types are not applied. The energy performance was considered mainly from the points of the tenants and end-users of office buildings. This thesis is a part of the NewWow (New Ways of Working) work package of the PRE (Built Environment Process Re-engineering) program

(NewWow) of RYM Oy. The object of NewWow is to produce the understanding about the changing nature of knowledge work and its requirements and consequences to management of organisations and spaces and for productivity. The interaction and project natured of knowledge work are answered by new space solutions that are developed by utilising BIM. (Rym Oy, 2011).

1.3 Structure of Thesis

This thesis work consists of a literary review and empirical research. The thesis begins with the literary review that is based on earlier research. At first, a general overview of the energy performance of buildings is given and the calculation methods and regulations of energy performance are presented. Then different measures to improve the energy performance of an existing office building are described. Both measures related to the users and technical solutions of an existing office building are studied. In addition, building commissioning and environmental assessment tools are presented. In the next chapter, the content and challenges of Green Lease are studied. Finally, the methods of investigating and improving the energy performance of a building, by building information modelling (BIM), are demonstrated.

The second and third sections consist of empirical research. The second section is based on a case study. At first, the chosen tenants were interviewed about the energy issues of the case building. The aim of the interviews was to study what sort of energy simulations would serve the tenants of the case building. Then, the energy efficiency of the case building was studied utilising the created light BIM of the case building. The energy performance, user behaviour and energy performance measures of the case building were simulated and analysed by Riuska energy simulation application.

The third section consists of a questionnaire study. Based on the results of the interviews and the energy calculations, an online survey for a larger amount of respondents was realised. The aim of the survey was to obtain the larger opinion of the office tenants about energy issues and study how a light BIM answers the demands of the tenants. The target group of the survey were the people who are responsible for the leases of different companies. The questions were mainly fixed choice questions and were analysed by quantitative methods.

At the end of the thesis, the conclusions are given based on given results from the literature review and the empirical study. In addition, the reliability of the results is evaluated and recommendations for extra research are given.

2 ENERGY PERFORMANCE OF BUILDINGS

This chapter introduces the calculation methods and legislation behind the energy performance of buildings. At first, the contents and calculations methods of energy performance are demonstrated. Then EU directive on Improving Energy Performance of Buildings (2010) is described and the implementation of the directive and related regulations are presented.

2.1 Definition and Calculation

The energy performance of a building consists of various factors, such as heating, cooling, lighting and electricity consumptions. The energy performance of a building is usually defined as a comparable, standardised use based energy consumption. Standardised use means that the factors that effect on energy consumption, including internal heat gains and ventilation rates, are standardised. Standardised energy consumption can be calculated by a floor area or cubic content for example and the consumption can be normalised to correspond average weather conditions. The energy performance calculation includes various X-factors. The most significant factors are the use of a building and the central basic parameters, such as used internal and external dimensions and the tightness of a building envelope. (Pietiläinen, et al., 2007).

The calculating methods of energy performance can be divided into two main groups:

1. Monthly based methods, such as ISO DIS 13790 and NBCF D5
2. Dynamic simulation methods where the calculation step is short, typically one hour, including IDA-ICE and RIUSKA.

The monthly based methods are easy to use and their initial data is lighter and clearer than in simulation methods. Their disadvantage is that internal temperatures cannot be calculated as with simulation methods. Moreover, cooling energy demand is easily calculated with the simulation methods. However, using the simulation methods requires experience and determining the initial values of the calculation is often laborious. (Pietiläinen, et al., 2007). If the initial values are delivered straight from design documents or building information models, the work will be reduced substantially. (Pietiläinen, et al., 2007; Langdon, 2012). The energy simulation based on BIM is studied more in chapter 5.3.

Calculating energy performance can be divided into three main parts:

1. Calculating the net demands of heating and cooling;
2. Calculating the energy consumption of technical systems; and
3. Calculating heat losses (Pietiläinen, et al., 2007).

In Finland, the Ministry of the Environment has given national regulations calculating the energy performance of a building, so called E-value (Decree on EPC, 2013). This calculation methodology is studied in chapter 2.4.

2.2 Energy Performance of Buildings Directive and Its Implementation in Finland

The European Parliament approved the recast Energy Performance of Buildings directive (EPBD) in May 2010. Its function was to advance the United Nations Framework Convention on Climate Change (UNFCCC), its long term commitment to maintain the global temperature rise below 2 degrees °C and its commitment to reduce the overall greenhouse gas emissions by at least 20 % below 1990 levels by 2020. EPBD tightens the requirements for energy performance both in new and existing building stock in the area of EU (Tekes, 2012). EPBD set goals and the basis which is supported and applied by national regulations. (Kaleva, et al., 2011). In Finland, the directive is implemented in the shape of new Building Codes, laws and decrees.

According to EPBD (2010) the used calculation methodology of the energy performance of a building may vary in national and regional level. The calculating methodology should cover the annual energy performance of the building and take into account existing European standards. The new national Building Code of Finland D3 - Energy Management in Buildings, gives instruction to calculating the annual energy performance of the building, so called E-value. The calculation methodology is reviewed in chapter 2.4.

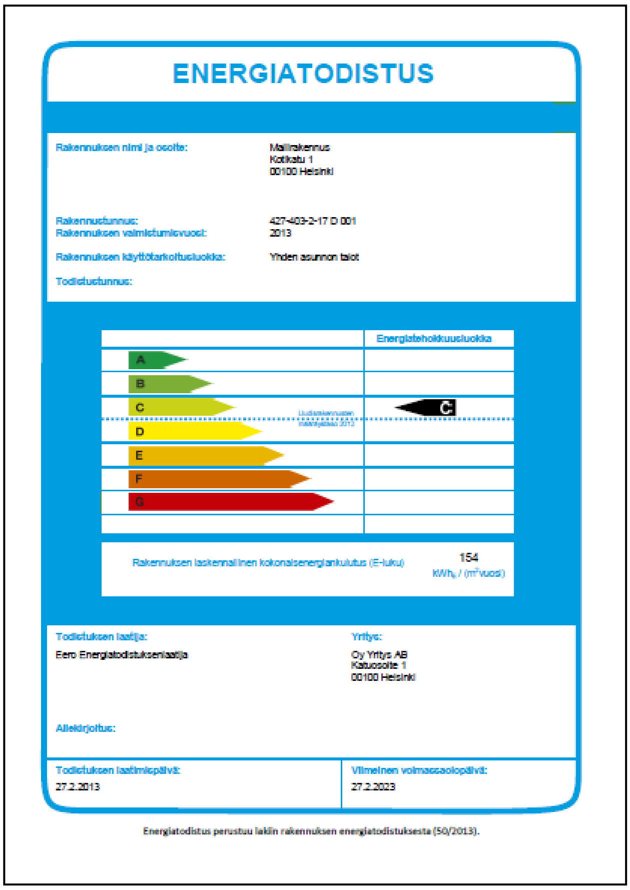
Other demand of EPBD is Energy Performance Certificates (EPCs) of buildings. EPC gives the prospective buyer and tenant liable information about the energy performance of a building or a building unit and advice on improving the performance. It also provides information about the actual impact of heating and cooling on energy consumption and carbon dioxide emissions. In Finland, the new law of EPC (50/2013) came into force at the beginning of June 2013 and it is studied in chapter 2.3

In addition, EPBD (2010) requires national minimum requirements for the energy efficiency in renovations. Energy efficiency measures should be limited to the elements that have the major significance by relative to energy efficiency. The Finnish Ministry of the Environment issued the decree on improving energy efficiency in renovations in February 2013. The decree came into force at the beginning of June 2013 for buildings in public use and on the first of September 2013 for other buildings. (Decree on Improving Energy Performance in Renovations, 2013/4). The content of the decree is reviewed in chapter 2.5.

2.3 Energy Performance Certificates

Energy Performance Certificate (EPC) has been developed for improving the energy performance of buildings and simplifying to compare different buildings with each other in the case of selling or leasing. EPC is in use in all European Union countries but it has been implemented nationally. It has been in use in Finland since 2008, when applying the building permit, as well as from 2009, in the case of selling or leasing of large buildings. (Ministry of the Environment, 2013a).

The new law of EPC (50/2013) came into force in Finland on the first of June 2013. New EPCs are based on calculated energy consumption when earlier the certificates were mainly based on realised consumption (Ministry of the Environment, 2008). In the new EPC, the energy efficiency rating is defined to a building or to a building part and it is not dependent on realised consumption or user behaviour. The energy efficiency rating is based on a calculated E-value. The cover page of new EPC is presented in Figure 1.



ENERGIATODISTUS

Rakennuksen nimi ja osoite: Mallirakennus
Kotikatu 1
00100 Helsinki

Rakennustunnus: 427-403-2-17 D 001
Rakennuksen valmistumisvuosi: 2013

Rakennuksen käyttötarkoitusluokka: Yhden asunnon talot

Todistustunnus:

Energiatehokkuusluokka

A
B
C
D
E
F
G

C

Rakennuksen laskennallinen kokonaisenergiankulutus (E-luku) 154 $kWh_E / (m^2 vuosi)$

Todistuksen laatija: Eero Energiatodistuksenlaatija

Yritys: Oy Yritys AB
Katuosoite 1
00100 Helsinki

Allekirjoitus:

Todistuksen laatimispäivä: 27.2.2013

Viimeinen voimassaolopäivä: 27.2.2023

Energiatodistus perustuu lakiin rakennuksen energiatodistuksesta (50/2013).

Figure 1. Cover Page of EPC (Motiva, 2013)

The calculation of E-value is presented in the methodology of National Building Code of Finland D3 (NBCF D3, 2012) and the decree on EPC (2013) of the Ministry of the Environment. The lower the E-value is, the more energy efficient the building is. If the realised energy consumption of present users is available, it must be informed in the certificate. In addition, cost-efficient recommendations to improve the E-value of a building have to be given in EPC. (Ministry of the Environment, 2013b).

The used rating system is determined by the use of a building. The energy efficiency ratings are divided into the classes A-G. The energy efficiency ratings of the different type of premises are presented in Table 1.

Table 1 Energy Efficiency Ratings of Different Type of Premises (Decree on EPC, 2013)

Purpose of use	Energy efficiency rating and E-value (kWh_E/m^2/vuosi)						
	A	B	C	D	E	F	G
Office building	-80	81-120	121-170	171-200	201-240	241-300	301-
Commercial building	-90	91-170	171-240	241-280	281-340	341-390	391-
Hotel	-90	91-170	171-241	241-281	281-341	341-450	451-
Educational building and kindergarten	-90	91-130	131-170	171-230	231-300	301-360	361-
Sports facility	-90	91-131	131-171	171-190	191-240	241-280	281-
Hospital	-150	151-350	351-450	451-550	551-650	651-800	801-

The new law of EPC (50/2013) is implemented gradually during the years 2013-2017. From the June 2013, EPCs have been mandatory in new construction and in the case of leasing or selling old detached houses or block of flats. For the detached houses built before the year 1980, EPCs are mandatory the first of July 2017 onward. For terraced houses, office buildings and commercial buildings the new law of EPC will be effective the first of July 2014 and for health care, educational, assembly facilities the first of July 2015. (Ministry of the Environment, 2013b).

If the value of a property is faint (below 50 000 euro), the rent is low (below 350 euro per month), the property is not presented in public or the sale is between close immediate families, EPC can be drawn up with a ready form, using a so called lightened method. In this case, visiting the property and giving the energy efficiency rating is not mandatory. In addition, EPCs are not required for the next buildings:

- Below 50 m^2 sized buildings;
- Vacation homes;
- Protected buildings;
- Manufactures;
- Repair shops;
- Temporary rented apartments;
- Greenhouses;
- Swimming halls;
- Ice stadiums; and
- Churches and other religious buildings that are used just for assembly. (Ministry of the Environment, 2013b).

In new construction, the certificate is a part of building permit documents. In the case of selling and leasing, EPC must be presented in showings and an energy efficiency rating must be visible in sales advertisements. (Ministry of the Environment, 2013b). When preparing EPC of an existing building an EPC expert has to determine the requisite information about the building from updated documents, visiting the building and interviewing the users of the building on demand. (Law on EPC, 50/2013).

Before several certificate forms, manners and validities were used. The purpose of the new law of EPC was to make EPC to be liable and comparable. The new EPC is valid for ten years. Preparing EPC can be combined for example with a condition survey or an energy audit. An EPC expert has to be qualified and registered in the register upheld by a controlling authority. To obtain the qualification, a suitable degree in technical science or compensatory working experience is required and a qualification exam has to be passed. The qualification is valid for seven years. Old and valid EPCs are valid according to their validity and the old qualifications of EPC experts are valid until maximum the year 2017. (Ministry of the Environment, 2013b).

2.4 E-value of Existing Building

2.4.1 Calculation Methodology and Tools

National Building Code D3 of Finland (NBCF D3), Energy management in buildings, was issued 30 March 2011. The regulations came into force on the first of July 2012 and applied only to the new construction. NBCF D3 (2012) collected separate energy efficiency orders and guidelines and tightened energy efficiency requirements about 20 %. (Kemppainen, 2011). D3 gives instructions how to calculate E-value, the annual energy performance of a building. Since the new law of EPC (50/2013) came on force the first of June 2013 onward, the calculation methodology of NBCF D3 (2012) and the instructions in the decree on EPC (2013) of the Ministry of the Environment are applied both to new and existing buildings when making EPC.

E-value is calculated for every building or separately for the different parts of the building. The E-value is the product of purchased energy and fuel-specific factors (Equation 1). It is expressed as a unit kWh_e/m^2 in a year:

$$\text{E-value} = \frac{\sum purchased\ energy \times fuel\text{-}spesific\ factor}{net\ heated\ area} \tag{1}$$

The fuel-specific factors represent the consumption of natural resources and the carbon dioxide emissions of the energy form (Vuolle, 2012). The idea of the factors is to encourage the use of renewable energy sources and reduction of the use of fossil fuels. The higher the factor of the used fuel is, the more the transfer in the building consumes natural resources. In other words, the higher the fuel-specific factor is, the less the energy demand of the building should be. (Kalliomäki, 2011). The fuel-specific factors are presented in Table 2.

Table 2 Fuel-specific Factors in E-value Calculation (Ministry of the Environment, 2013a)

Fuel	Factor
Fossil fuels	1
Electricity	1.7
District heating	0.7
District cooling	0.4
Renewable fuels	0.5

To existing buildings, buildings with no cooling, or buildings where cooling is only used in the individual spaces, energy calculation can be carried out by a monthly method. The used monthly methods are presented in National Building Code of Finland D5 (2012) or in standard SFS_ISI 13790 (2010). For all the other new buildings, the energy calculation should be carried out with a dynamic calculation tool following calculation instructions in NBCF D3 (2012) (Decree on EPC, 2013). The calculation tool must be validated duly according to EN, CIBSE or ASHRAE standards or equivalent IEA BESTTEST test cases. (Vuolle, 2013).

2.4.2 Purchased Energy Consumption

The purchased energy is energy that is delivered and bought outside. It can consist of renewable or fossil fuel and it can be delivered from the grid, the district heating network or the district cooling network. (Decree on EPC, 2013). The renewable energy that a user produces locally from renewable energy sources, so called on site renewable energy, has no fuel-specific factors. Its use reduces the purchased energy and consequently also the E-value of the building. On site renewable energy is such as local wind energy, energy produced from solar panels and collectors or the heat source of a heat pump. In the calculation, just that part of the on-site renewable energy is taken into account, which reduces the purchased energy consumption. (Decree on EPC, 2013).

The purchased energy consists of the energy consumption of heating, cooling, ventilation, equipment, lighting and domestic hot water supply. The system boundary of the purchased energy consumption is presented in Figure 2.

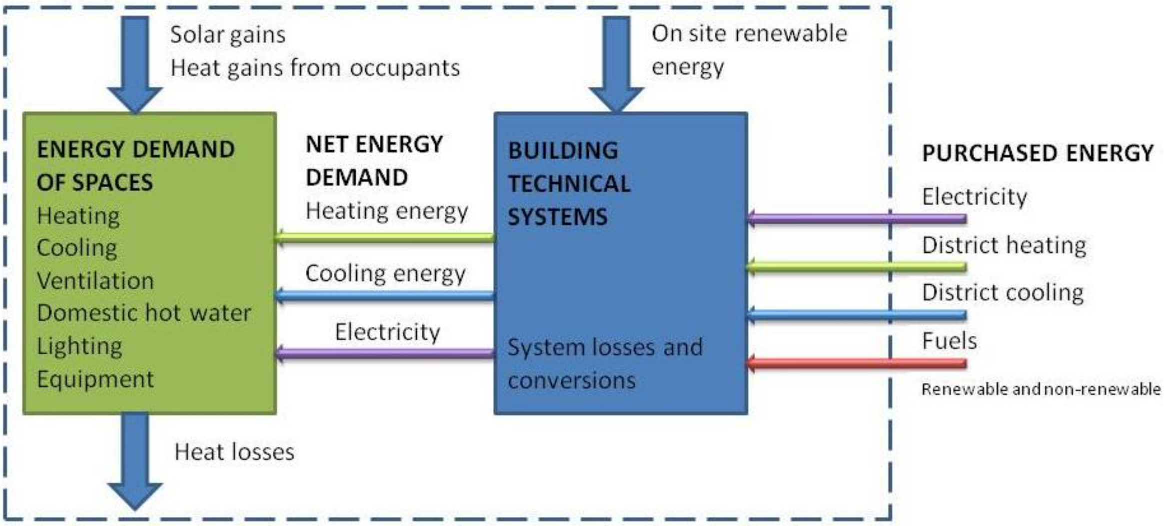


Figure 2 System Boundary of Purchased Energy (Decree on EPC, 2013)

2.4.3 Initial Data

The initial data of calculation can be design values, values from other documents such as drawings or building information models or values which have been founded in touch with an inspection. The initial data can also be based on the National Building Codes used during the building permit or instructions been followed in the building project. If the initial data is not available, the default values in accordance with the pendency year of the building permit are used. The default values are presented in the decree on EPC (2013).

Standard Use

The calculation of E-value is carried out with standard use and the changeable consuming habits of users are not considered (Kalliomäki, 2011). The standard use means the fixed ventilation running time, the electricity use of lighting and equipment and the heat gain from people. The purchased energy consumption of a building or a buildings part is calculated according to the weather zone I, the Helsinki-Vantaa weather conditions of NBCF D3 (2012, p.29-30). The purchased energy consumption is calculated by the fixed rate bases:

- Indoor climate conditions,
- The standard use of a building and internal heat gains and
- Consumption of domestic hot water.

The indoor climate conditions of the different types of premises used in the calculation are presented in Table 3.

Table 3 Set Point Temperatures and Ventilation Rates of Operation Time (NBCF D3, 2012)

Purpose of use	Outdoor air change rate	Heating limit	Cooling limit
	l/(s m²)	°C	°C
Office building	2	21	25
Commercial building	2	18	25
Hotel	2	21	25
Educational building and kindergarten	3	21	25
Sport facility	2	18	25
Hospital	4	22	25

The internal heat gains equivalents to the standard use of the premises are presented in Table 4. The operating period refers to the amount of hours the building is used in a day. The utilisation rate consists of the average presence of people and the average utilisation rate of lighting and equipment. (NBCF D3, 2012).

Table 4 Standard Use and Internal Heat Gains (NBCF D3, 2012)

Purpose of use	Time	Operating period		Utilisation rate	Lighting	Equipment	People
		h/24h	d/7d	-	W/m²	W/m²	W/m²
Office building	07:00-18:00	11	5	0,65	12	12	5
Commercial building	08:00-21:00	13	6	1	19	1	2
Hotel	00:00-24:00	24	7	0,3	14	4	4
Educational building and kindergarten	08:00-16:00	8	5	0,6	18	8	14
Sport facility	08:00-22:00	14	7	0,5	12	0	5
Hospital	00:00-24:00	24	7	0,6	9	9	8

The heat loss of people in Table 4 does not include the latent heat loss. The total heat loss of people is calculated dividing the value by factor 0.6. The heat gain caused by people is calculated based on the heat losses (W/m^2) of Table 4. The alternative method calculating the heat gain is based on the occupant densities presented in Table 5. In this case, 125 W is used as a total heat loss of a person, except in schools and kindergartens 110 W is used. (NBCF D3, 2012).

Table 5 Occupant Densities (per/m^2) (NBCF D3, 2012)

Purpose of use	Occupant density
	per/m²
Office building	1/17
Commercial building	1/43
Hotel	1/21
Educational building or kindergarten	1/5
Sports facility	1/17
Hospital	1/11

Heated Net Area

A heated net area is the sum of heated floor areas and includes the rounded interior surfaces of external walls. The heated net area can also be calculated from a gross heated area where the area of the building element of the external walls is reduced. Alternatively, the heated net area of an existing building can be estimated to be 90 % of the gross area.

If the gross area is not known, it can be estimated according to external dimensions and number of layers. The heated net area is calculated reducing the area of unheated spaces from the gross area. The semi-exterior spaces, such as attics and storages, are treated as heated spaces. The unheated spaces are not considered and their area is not taking into account in the calculation. (Decree on EPC, 2013)

Areas of Building Elements

The areas of the building elements of a building envelope are defined pursuant to the total internal dimensions of the building. The area of a base floor is calculated according to internal dimensions not reducing voids and the area of structures. The area of a roof is calculated pursuant to the internal dimensions of external walls reducing the areas of skylight wells. The area of external walls is calculated according to the internal dimensions from the floor surface of a base floor to the soffit of a roof reducing the areas of the voids of windows and doors. The areas of the windows and doors are calculated according to the external dimensions of a frame. (Decree on EPC, 2013)

Structures

The heat transfer coefficients of structures are determined in an inspection or in updated building documents. Alternatively, the heat transfer coefficients pursuant to Appendix 1 of the decree on EPC (2013, p. 5) can be used. The used values for the solar heat gain coefficient of the perpendicular solar irradiance of the light opening of a window, $g_{perpendicular}$, are defined in a product specification or if the values are not available, the value 0.6 will be used. If the calculation method attribute to the NBCF D5 (2012) is used, the used value for the total correction factor of the penetration of the solar irradiance, $F_{penetration}$, will be 0.5 or more detailed value if it is available. In other methods, factors equivalent of their effect can be used. (Decree on EPC, 2013)

The heat losses of the joints of heat bridges between structures must be calculated. The specific heat losses and lengths of the heat bridges between structures are determined according to the documents of a building. If the defined information is not available, the values presented in the NBCF D5 (2012, p.19) can be used. For existing buildings the effect of the heat bridges can be estimated simply by adding 10 % to the conduction loss of an exterior envelope. The internal effective heat capacity of a building is defined based on the building properties. If the defined information is not available, the values presented in NBCF D5 (2012, p.39) can be used. (Decree on EPC, 2013).

Ventilation

The presented values according to the purpose of use in NBCF D3 (2012) are used for the running times and air quantities of ventilation. The ventilation is set on one hour before the operating time and is set off one hour after the end of the operating time, unless the building is not used continuously. The design values of the air quantities are used as calculation values for the spaces with demand controlled ventilation. (NBCF D3, 2012) .

When calculating the net demand of the heating energy and electricity consumption of the ventilation, the annual efficiency (%) of the heat recovery of a ventilation system and the specific output (kW/m^3/s) are taken from the updated documents of a building or determined in an inspection. Alternatively, the values in the Appendix 1 of Decree on EPC (2013, p. 6) can be used. The electricity use of the ventilation system consists of electricity consumption of the fan and auxiliaries (pumps, frequency drives, control devices). The net heating demand of the ventilation system is a heating energy which consists of heating the air after a heat recovery to the temperature of a supply air and possible heating before the heat recovery to prevent freezing. (NBCF D3, 2012) .

Infiltration air

The air infiltration rate of a building is calculated by the method presented in NBCF D3 (2012) from the building envelope infiltration value q_{50}. The q_{50} refers to the average infiltration rate of the building envelope in one hour with the pressure difference of 50 Pa. The q_{50} of the building envelope of an existing building can be defined by measuring or from the building updated documents. Alternatively, it can be determined based on the values in the Appendix 1 of decree on EPC (2013, p. 7). The q_{50} can be calculated from the building infiltration value n_{50} by a formula

$$q_{50}=\frac{n_{50}}{A_{envelope}}V \qquad (2)$$

where

q_{50} building envelope infiltration value with the pressure difference of 50 Pa, m3/(h m^2)

n_{50} building infiltration value with pressure difference of 50 Pa, 1/h

V Space volume, m^3

$A_{envelope}$ Building envelope area, m2. (Decree on EPC, 2013).

Domestic hot water

The net energy demand of domestic hot water (DHW) is calculated based on the values of Table 6. The cold water temperature is 5 °C and the hot water temperature is 55 °C. (NBCF D3, 2012).

Table 6 Specific Consumption of DHW and Equivalent Net Energy Demand (NBCF D3, 2012)

Purpose of use	Specific consumption of DHW	Heating energy
	$l/(m^2 a)$	$kWh/(m^2 a)$
Office building	103	6
Commercial building	68	4
Hotel	685	40
Educational building and kindergarten	188	11
Sport facility	343	20
Hospital	515	30

The purchased energy of DHW is calculated from the net energy demand taking into account the losses of distribution, circulation, storage and supply. The efficiency of DHW distribution can be investigated by an independent survey or using values in Appendix 1 of decree on EPC (2013, p. 8). Similarly, the specific capacity of the heat loss of a circulation line can be investigated by an independent survey or use values in Appendix 1 of decree on EPC (2013, p. 8).

The length of a circulation line is investigated from the documents of a building or the value in Appendix 1 of decree on EPC (2013, p. 8) can be used. The loss of the storage of DHW circulation is determined in the inspection of the building or the value in Appendix 1 of decree on EPC (2013, p. 9) can be used. The 50 % of the losses of the circulation and storage of DHW circulation will be included in the heat output of spaces if it is not proved otherwise by calculation. The electricity consumption of a DHW circulation pump is calculated attribute to method presented in NBCF D5 (2012) or in other equivalent way.

Heating system

The energy consumption of space heating is calculated dividing the net heating energy demand of spaces by the efficiency of the heat distribution and rejection of the heating system. The annual efficiency and electricity consumption of accessories can be investigated by an inspection or the values in Appendix 1 of decree on EPC (2013, pp. 10-11) can be used.

When calculating the heating energy consumption of ventilation, the value 1.0 is used for the efficiency of the heating radiators of a ventilation machine. The purchased energy of the heating system is calculated dividing the energy consumption of spaces, ventilation, DHW and the possible loss of the separate heat storage by the efficiency of the heat supply system in question. The efficiencies can be determined in touch with an inspection, in the production properties of devices or the values presented in Appendix 1 of EPC (2013, p. 11) can be used.

If there is a heat pump used for the heating in a building, its heat production and electricity consumption calculation will be made by the method presented in NBCF D5 (2012) or the other equivalent method. The SFP-Numbers of the heat pumps can be investigated in the touch with the inspection of the building or use the values presented in Appendix 1 of EPC (2013, p. 12).

Electricity

The electricity consumption of a building consists of the electricity consumption of ventilation system, accessories, heating, cooling, equipment and lighting. The electricity used for the spaces and supply air is calculated to be a part of the heating system. The electricity consumption of lighting and equipment is calculated by the methods presented in NBCF D3 (2012).

Cooling

The energy consumption of cooling will be included in purchased energy consumption only if there is a cooling system in a building. In a building where cooling is only found in individual spaces, the energy consumption of the cooling system can be excluded from the calculation. The energy consumption of the cooling system consists of the production of the cooling energy and electricity consumption of accessories. The net demand of the cooling system: spaces and ventilation, is calculated by the standard use of NBCF D3

(2012) and by a dynamic calculation tool that meets the requirements. The energy consumption of the cooling system is calculated from the net demand of the cooling energy taking to account the losses of produce, storage and distribution and transitions, by the method presented in NBFC D5 (2012) for example. The cooling energy consumption of existing buildings can also be calculated by the alternative method presented in the Appendix 1 of decree on EPC (2013, pp. 14-15).

2.4.4 Shortages and Problems

E-value is mainly based on tabular or standard values, just a few real building features are used in the calculation. The essential factors such as actual ventilation rates and the use of lighting and user equipment affecting the energy consumption of buildings have been eliminated to simplify the calculation. It is important to understand that E-value considers and compares the calculated energy performance of buildings and the real energy performance is another matter. (Kiiskinen, 2012)

In new construction, E-value operates as a simple factor in comparing different design solutions. In existing buildings, the benefit of E-value calculation is questionable for many reasons. The purpose of EPC is to compare the energy performance of different buildings but it is probable that differences cannot be seen between different existing buildings. It is possible that the buildings of the same group are given the same energy efficiency rating and even the same E-value because the initial data of the calculation is the same. (Kiiskinen, 2012).

Moreover, there can be significant differences in results if the initial data are taken from design values, from tables or values found in a visit are used. Many important measures to improve the energy performance of buildings are not considered in E-value calculation. These are for example energy consumption monitoring, regular audits, thorough energy audits and energy efficiency contracts. (Kiiskinen, 2012).

2.5 Requirements Improving Energy Performance in Renovations

There is huge potential in the existing building stock to decrease energy consumption and carbon dioxide emissions. The challenge is to find ways of improving energy efficiency and the use of renewable energy cost efficiently in renovations. (Tekes, 2012). The energy performance section was added to the law on Land use and construction (958/2012) the 21st of December 2012 and consequently the Finnish Ministry of the Environment gave a decree of improving the energy performance in renovations on the 27th of February 2013. The decree (2013/4) came into force for the buildings used by authorities on the first of June 2013 and for other buildings on the first of September 2013. The minimum requirements to the energy performance are defined when it is in question on licensed renovations, changing the purpose of use or revising technical systems. Starting the renovation is still voluntary and a property owner can self-decide the best measures to improve energy efficiency within the limits of decrees. (Ministry of the Environment, 2013c).

The decree (2013/4) refers no to the projects of which licence application has been left before the regulation came into force. In addition, the decree refers no to vacation homes, greenhouses, protected buildings, buildings smaller than below 50 m^2 of its size, buildings used for religious operation and manufactures which do not need much extra heating. In energy performance calculation and presenting the improvements in consequence of the renovation, the decree on EPC (2013) and NBCF D3 (2012) are applied. When planning the renovation, the energy performance measures of a building, should be presented. If the features of a building according to the purpose of use are improved, the energy consumption may grow a calculated amount caused by the improvement. (Decree on Improving Energy Performance in Renovations, 2013/4).

In the decree (2013/4), three alternative methods are presented to improve energy efficiency in renovation:

1. Improving insulation and air tightness to the values in agreement with the requirements (Decree on Improving Energy Performance in Renovations, 2013/4);

2. Decreasing calculated energy consumption in standard use without fuel-specific factors ($kWh/m^2/year$) to the level required (Decree on Improving Energy Performance in Renovations, 2013/4). In this case, the requirement of an office building is $\leq$ 145 kWh/m^2 (Kauppinen, 2013); and

3. Decreasing E-value ($KWh_E/m^2/year$) to the required level (Ministry of the Environment, 2013c). The required E-value of an office building is $\leq$ 0.7* initial E-value. (Kauppinen, 2013).

Moreover, the requirements to technical systems when they are renovated, improved or renewed are given in the decree (2013/4). It is important to ensure that the technical systems of a building such as heating and ventilation operate and their basic controls are verified always, when the changes which effect on the operation of the systems, are being made. The changes are for example insulation, improving air tightness and revising the systems. (Ministry of the Environment, 2013c).

3 IMPROVING ENERGY PERFORMANCE OF EXISTING OFFICE BUILDINGS

This chapter concentrates on the energy performance of existing office buildings and how it can be improved. At first, the distribution of energy consumption in office buildings is described. Then the different solutions for improving energy performance are presented related to the end-users and technological solutions of office buildings. In addition, existing building commissioning and environmental assessment methods are presented.

3.1 Energy Consumption in Office Buildings

The use of buildings is about 40 % of the total energy consumption so it has a significant impact on energy consumption and greenhouse gas emissions (Ministry of Employment and the Economy, 2009). The portion of the new construction of the whole building stock is small, only 1-2 %. Therefore the focus of the construction is transferring from the new construction to renovation, why the existing building stock makes the essential saving potential (Kauppinen, 2013). Compared with the other building types, energy consumption in office buildings is one of the highest. The annual energy consumption in office buildings differs between 100 and 1000 kWh per square meter. (Santamouris & Dascalaki, 2002)

The energy consumption of the building consists of:

▪ heating energy consumption

- space heating ($T_{indoor\ air}$ =21-24°C)
- ventilation heating ($T_{total\ ar}$ =16-18°C)
- domestic hot water (T_{dhw} = 55°C);

▪ cooling energy consumption

- space cooling ($T_{indoor\ air}$ =21-24°C)
- ventilation cooling ($T_{total\ ar}$ =16-18°C); and

▪ electric energy consumption

- lighting electricity
- electrical equipment
- other HVAC-electricity, such as pumps and fans. (Lappalainen, 2010, p. 45).

Energy in office buildings is mainly consumed for heating, cooling and lighting purposes; however a substantial portion of consumption is the office equipment. (Santamouris & Dascalaki, 2002). The general distribution of heating energy consumption in an office building is presented in Figure 3. The ventilation heating causes a significant part, almost 30 % of the heating energy consumption.

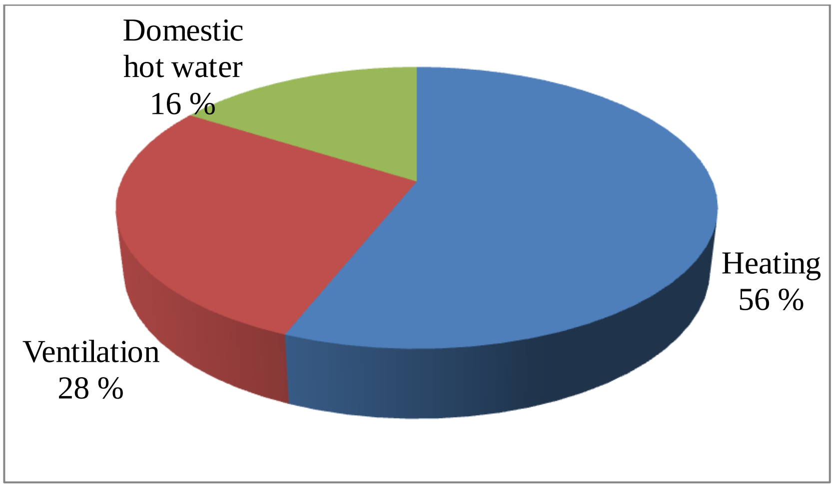


Figure 3 Heating Energy Consumption in Office Building (Granlund, 2008)

The general distribution of electricity energy consumption in an office building is presented in Figure 4. Lighting and the use of office equipment cause 70 % of electricity consumption.

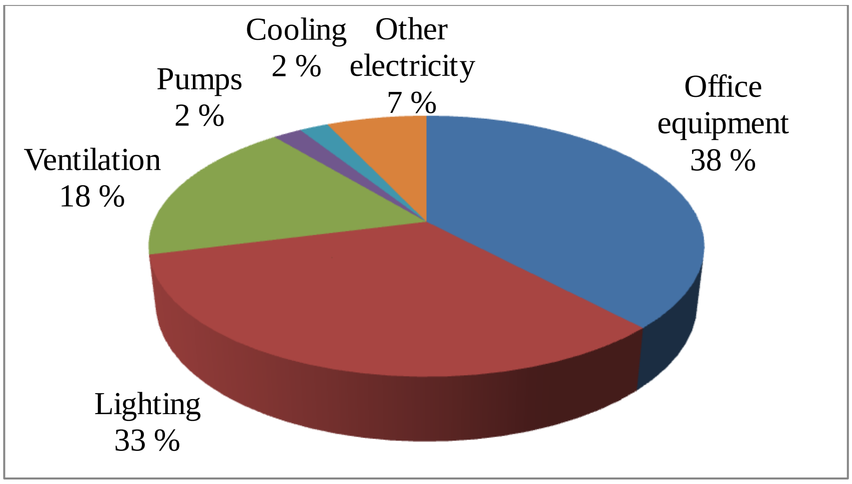


Figure 4 Electricity Energy Consumption in Office Building (Granlund, 2008)

3.2 Effect of End-Users

Typically, the end-users of buildings are responsible for space efficiency, energy management needed for user's operations, water consumption and waste management (Kaleva, et al., 2011). With technical solutions significant energy savings can be achieved in a short time but as long as technology is operated by end-users, the failure of the human factor can fail the whole operation. The appropriate use of systems and equipment in the property and the behavioural change of end-users have the same or even more energy saving potential than technological solutions and renovations have (Ministry of Employment and the Economy, 2009; Masoso&Grobler, 2009).

It is proved that more than 50 % of the energy is used during non-working hours than during official working hours. Studies show that the main consumers are air-conditioning systems, lighting and equipment, such as computers that have been left on at the end of the day. (Masoso & Grobler, 2009). Moreover, the study of Junnila (2007) reveals that the potential energy conservation of the enhanced use of office equipment estimated to range from 60 % to 80 % depending on the case and for lighting approximately 30 % in all the cases. In that case, the total energy conservation equals about 20 % of the overall electricity consumption of the case organizations (Junnila, 2007).

Behavioural change can be put into practise without any extra investments in the large existing stock of buildings (Masoso & Grobler, 2009). Most of the end-users of buildings do not have a clear idea of how much energy they are using for different purposes and what sort of difference they could make changing their behaviour. In multitenant buildings, the energy expense is often charged relative to rented areas, which decreases the motivation of users further to be interested in their energy consumption (Vehosmaa, 2008). Users need the feedback of their behaviour to evaluate their energy consumption and make it more visible. (Darby, 2006). Clearly communicated and constant feedback is essential for a lifelong change in user behaviour (EEA, 2013). Moreover, it is important to notice that the behavioural change is not linked just to the facility but to the whole organisation. So when end-users move to new premises, the improved performance in energy management stays with the organisation. (Junnila, 2007).

The technical report of EEA (2013) gives different measures to give feedback to the users of buildings. Direct feedback is available on demand and includes a range of systems designed to give real-time access to energy consumption information, for example direct displays and smart meters. Indirect feedback is a raw data processed by an expert and it is sent out to customers, for example frequent bills based on historical feedback about energy consumption and comparison the energy consumption to earlier or the similar building types. The purpose is to provide property users more information about how much energy they use and how much it costs them in economic and environmental terms. The third feedback form is energy audits which investigate the energy-efficient condition of a property, potential savings, possible investments and their profitability (Granlund, 2013). Although the energy audits tend to focus more on measures that require investments, they can be successful in raising awareness about energy issues, a prerequisite for changing behaviour and consumer habits. (EEA, 2013). According to the report of EEA (2013) the best results are achieved when different measures to deliver feedback are combined.

There are various measures that the end-users of an office building can be implemented to improve energy efficiency. The most important measures are to shut down all the office equipment and lights when they are not in use. Lights should always be switched off when the space is left for over ten minutes or there is nobody in the space. Almost 75 % of electricity consumption of the computers can be achieved if the computers and screens are shut down when they are not in use. (Sponda, 2010). The easiest solution is that all the office equipment of a personal work place can be switched off with one switch after the work day (Vehosmaa, 2008). In addition, the powersave modes of office equipment, such as computers, screens, printers, decrease the electricity consumption significantly. Energy efficient equipment should be favoured, for example portable computers consume just about 10 % of the electricity consumption of desktop computers. Unnecessary printing should be avoided and electrical data management should be increased so that the paper consumption would be minimised. (Sponda, 2010).

Other measures related to energy efficient use are favouring stairs instead of a lift and making coffee and tea just in need. Moreover, the useless running of water should be avoided and hot water usage should be decreased. If an office worker notices problems with heating, cooling or water appliances, it should be informed to the maintenance staff as soon as possible to avoid energy waste. (Sponda, 2010).

3.3 Technological Solutions

3.3.1 Evaluation of Energy Performance Measures

To maximise the energy performance of a building, the appropriate use and behavioural change of end-users is not always enough and new technological solutions are needed. To achieve cost-effectiveness, energy performance measures should be done in the touch with the other renovation. Usually, the renovations of an existing building stock fall upon windows, doors, facades, and water, sewer and ventilation systems. Often electricity systems are also renewed separately or in the touch with the other renovation. In recent years, the significant part of, particularly in the 1960-1970 constructed, buildings have to be renovated. (Kauppinen, 2013).

The first step when considering renovation is to investigate how energy is consumed and how the consumption can be decreased in a building. Appropriate methods for this are energy performance certificates and energy audits (Ministry of the Environment, 2013d). EPC can be also a part of an energy audit. EPC makes comparing the energy consumption of buildings easier whereas the energy audit is a thorough survey about the energy consumption and water use of the property (Ministry of the Environment, 2013d). The energy efficiency measures based on EPCs or energy audits can be applied to the maintenance and repair programme of a property (Ministry of the Environment, 2013d). Correctly planned and implemented energy efficiency measures improve working and livings circumstances and prevent humidity damages and mould problems. (Ministry of Employment and the Economy, 2009). The technological solutions of office buildings to improve energy performance are viewed in next chapters.

3.3.2 Ventilation

A functional ventilation system delivers fresh air for heating and erases impurities in a building. When ventilation is based on the pressure differences that are achieved either naturally by the join effect of temperature difference and or by fans when it is called mechanical ventilation. (FiSIAQ, 1996). The important matter when considering an energy efficient ventilation is to ensure the running times of the ventilation should respond to the use of an building (Ministry of the Environment, 2013d).

In office buildings, the utilisation rate is smaller than in residential buildings, so the control of the ventilation is even more important. There are also more local exhausts for example in toilets where there is not a heat recovery and therefore energy is lost more. (Heljo & Vilhola, 2012). It is important to take into account demand controlled ventilation and the correct controls of supply and exhaust valves. The demand controlled use of the ventilation can be controlled automatically by the occupancy, temperature and moisture sensors or time control. (Motiva, 2010).

Efficient and often used method to decrease the energy consumption of the ventilation system is to replace old natural ventilation system or fan assisted exhaust ventilation system by new fan assisted balanced ventilation system with a heat recovery. (Motiva, 2010). In this case, the electricity consumption can be increased but at the same time the air quality is increased (Motiva, 2011). According to the decree of renovations (2013/4), the Specific Fan Power (SFP) of the renewed fan assisted balanced ventilation system can be maximum 2.0 kW/ (m^3/s). When renovating ventilation system the most important issue is the heat recovery efficiency. It affects the pay pack time of the investment even more than the price of the ventilation machine (Motiva, 2011).

The purpose of a heat recovery is to transfer heat from exhaust air to incoming air (Soininen, 2009). Under the decree (2013/4) of the Ministry of The Environment on Improving Energy Performance in Renovations (2013/4) the annual efficiency of the new heat recovery should be at least 45 %. The annual efficiency tells how many per cent of the heat demand of the ventilation is covered by a heat recovery (Soininen, 2009). Already with a basic solution of a cross flow heat exchanger the demand of the decree (2013/4) is reached by the annual efficiency of 50 %. With a counterflow heat exchanger the annual efficiency of 60 % is achieved and with a rotatory heat exchanger the annual efficiency of 70 % is achieved. (Heljo & Vilhola, 2012).

3.3.3 Cooling

The energy consumption of the cooling of buildings has been increased and is still increasing in Europe and worldwide. Many reasons for this rise can be found, such as increase of internal loads (IT-equipment, lighting), climate change, tightened requirements on indoor comfort and the misconduct of occupants. The highest ratio of cooling energy consumption can be found in office buildings. (Staller & Tisch, 2011). The most of the cooling systems for the buildings are based on electrical energy and the used coolant includes hazardous HCFC-compounds, therefore the cooling systems have enormous negative environmental impacts. To decrease the environmental impact of cooling the alternative cooling strategies should be found. The important measures for existing office buildings are: adding solar shading elements, adding passive night ventilation or using district cooling instead of mechanical cooling. (Staller & Tisch, 2011; LVI 34-10462, 2010).

The used solar shading elements of buildings are sunproof glasses, blinds, awnings or louvers (Holopainen, et al., 2007). Depending on the climate zone and type of shading, reductions in cooling energy demand are from 10 to 70 % (Staller & Tisch, 2011). To prevent the heat effect of solar radiation, it is the cheapest that solar shading is the outside of a window or the most possible near the external surface of the window. Adjusted louvers or rolling blinds are active solar shading methods and they make the utilisation of the heat energy of solar radiation possible when it is needed. Instead, the solarproof glasses and integral louvers decrease the solar radiation also when it could be utilised and so the heat demand of the building can be increased. (Holopainen, et al., 2007). There are two basic types of sunproof glasses: reflecting and absorbing glasses. The direct light cannot be fully protected with the sunproof glasses as with other solutions. In addition, adjustable solar shading glasses have been developed. Their total transmittance of the solar radiation can be modified for example by an electric current or by the temperature. Their becoming common has been slow because of the high price, longevity problems, and the slowness of darkening and bleaching. (Holopainen, et al., 2007).

In passive night ventilation, the room air temperature and structures are cooled by colder external air. It is studied that the passive night ventilation enables 0.8-2.5 C degrees reduction in the room temperature in the first hours of the morning and the total cooling energy demand can be decreased 10-40 % depending on the climate zone. (Soininen, 2009; Staller & Tisch, 2011). In district cooling, any coolants are not used and 80 % of its production is based on energy that would otherwise be unutilised (Helsingin Energia, 2013). Helsingin Energia produces the district cooling energy by utilising cold see water, the heat content of purified waste water and overheat from combined heat and power production. The district cooling is incomparable by its energy efficiency compared with the mechanical cooling system because it utilises otherwise wasted energy. (LVI 34-10462, 2010). Therefore, the district cooling has the lowest fuel-specific factor 0.4 when calculating E-value. (NBCF D3, 2012). In 2010 there were approximately 170 district cooling connections in Helsinki, Finland and their connected cooling load was about 100 MW. It is estimated that the district cooling load will exceed 250 MW in 2020. (Helsingin Energia, 2013). The estimated development of district cooling power in Finland is presented in Figure 5.

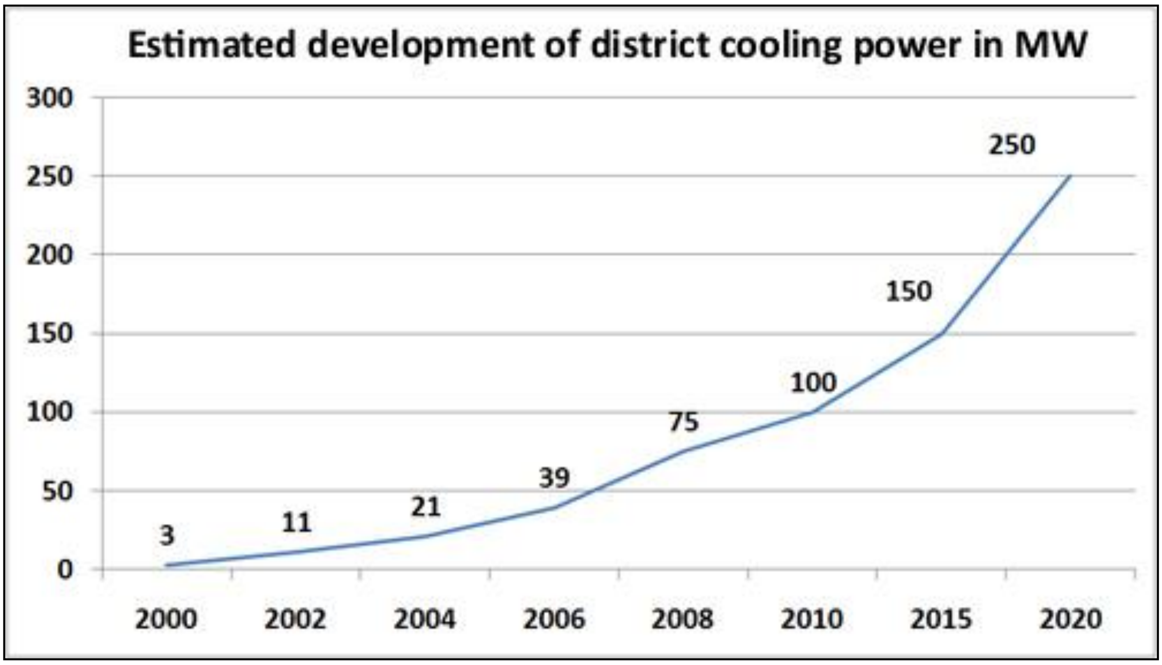


Figure 5 Estimated Development of District Cooling (Helsingin Energia, 2013)

The energy efficiency of cooling can be also improved by energy efficient equipment and the right placement of cooling devices. The use of energy efficient lighting and equipment with low rejected heat reduces the internal cooling load of the office buildings up to 30 %. Usually the supply vents of the air conditioning are located high in the office buildings (CAC = ceiling-based air-conditioning). In FAC (floor-based air-conditioning) system the air-conditioning is placed low when the cooling air can be blown straight to the occupied zone, the higher supply temperature can be used and less energy is needed to offer the same cooling demand than the CAC-system. In the CAC-system, the supply air has to be colder because it mixes together with the warm indoor air and warms up when moving along to the occupied zone. When the FAC-system is used, energy can be saved about 7 %. (Soininen, 2009; Staller & Tisch, 2011; Gao, et al., 2009).

3.3.4 Heating

In Finland, cold climate sets challenges for the heating and energy consumption of buildings. Energy should be saved but same time healthy and safe indoor environment should be ensured for the users of buildings. (Soininen, 2009). In the buildings, where the use is not constant, such as in office buildings, it is possible to save energy by irregular heating. It means that the room air temperature is decreased, to 12-16 C degrees for example, when the building is not in use for a long time. The prerequisite for the irregular heating is to ensure that thermal comfort prevail during the operating period. (Soininen, 2009; Lappalainen, 2010).

In old office buildings, 30 % of the heating consumption results from the heat energy consumed by ventilation (Granlund, 2008). When the basic renovation is done to the old building, usually ventilation systems are renewed and a heat recovery is applied to them. The heat consumption can be reduced 15-20 kWh/rm^2. The yearly saving potential of the heating energy of the office building stock will be even 30-50 million euros if 5 % of the old stock is renovated yearly. (Holopainen, et al., 2007).

If a heating system is replaced or changed to improve the energy efficiency of the office building, it will be important to consider the fuel-specific factors that impact on E-value. Electricity use should be avoided because it has the highest factor 1.7. The district heating (0.7) and renewable fuels (0.5) should be favoured because they decrease the E-value with their low fuel-specific factors. (NBCF D3, 2012). Other important factors that affect the heat consumption of the office building are reviewed next.

Thermal Insulation

The requirements for the thermal insulation of buildings have tightened during the decades while the thermal insulations and technologies were being developed. External walls compose the largest part of the envelope of a building so they play a significant part of the heat loss. In particular, in old buildings the thermal insulation of external walls is poor comparing to the recent requirements. (Holopainen, et al., 2007). The enormous part of the buildings stock was built in 1960-1970 and the typical structures of external walls have clearly exceeded their technical lifetime and need repair. Thermal insulation improvement is the most profitable to do simultaneously with another renovation, for example when the damaged windows are replaced by new windows or the rendering of an external surface is renovated. (Holopainen, et al., 2007).

According to the decree (2013/4) the U-Value (W/m^{2}K) of renovated external walls and roof should be decreased at least half of the initial value or even to the required level of new buildings ensuring that the building envelope operate structural physically correct after the renovation. To a base floor supplementary heat insulation should be done in the realms of possibility. The supplementary insulation of external walls can be realised most easily from outside but it can also be done from inside or the heat insulation can be changed to a better one. The supplementary heat insulation of a base floor is possible done by adding the heat insulation layers or changing the heat insulation to a better one. Changing the heat insulation of the base floor will be typically cost-effective if the surface material has to be changed. (Holopainen, et al., 2007). The supplementary insulation of the roof of a building is usually uncomplicated and profitable (Lappalainen, 2010). The most reliable is to use the same insulation as it is initially used in the building. (Holopainen, et al., 2007).

Air Tightness

Improving air tightness reduces uncontrollable leakage airflow. The air leakage is caused from the joint of the building elements, inlets and the lack of seals. The easiest and cheapest way to improve the air tightness is renovating window and door seals. The other significant and easily implemented way is the compaction of a joint between the frames of windows and doors and walls. When improving the air tightness of a building, it is important to ensure that ventilation stays adequate also after the renovation. (Holopainen, et al., 2007).

Windows

Even if the total area of windows is just 10-15 % of a surface area, the heat loss through the windows can be the same class as through external walls. The reason for it is that the windows have a notably higher thermal transmittance than the external walls have. (Holopainen, et al., 2007). The portion of the windows of the heat demand of buildings is usually 15-25 %. The major influence on the energy consumption of a building is achieved by renewing windows and installing supplementary glasses. (Hemmilä & Saarni, 2001, p. 61). Applying developed glass technology the heat loss of windows can be even halved. In addition, sealing and installing louvers decrease the heat consumption of windows (Hemmilä & Saarni, 2001, p. 61). Windows are the most cost-efficient to change in the end of their lifetime. (Kauppinen, 2013).

External doors present about 3 % of the energy consumption of a building. If the heat insulation of a building envelope is improved, it will be profitable to improve the heat insulation of the external doors. The best result is achieved with good sealing. (Lappalainen, 2010, p. 39). The thermal transmittance (U-value) of new windows and external doors should be 1.0 W/m^{2}K or better (Decree on Improving Energy Performance in Renovations, 2013/4).

3.3.5 Lighting

The energy efficiency of lighting consists of three main components: way of lighting, demand controlled use and the environment (Kallasjoki, 2011). The principles of energy efficient lighting are presented in Figure 6.

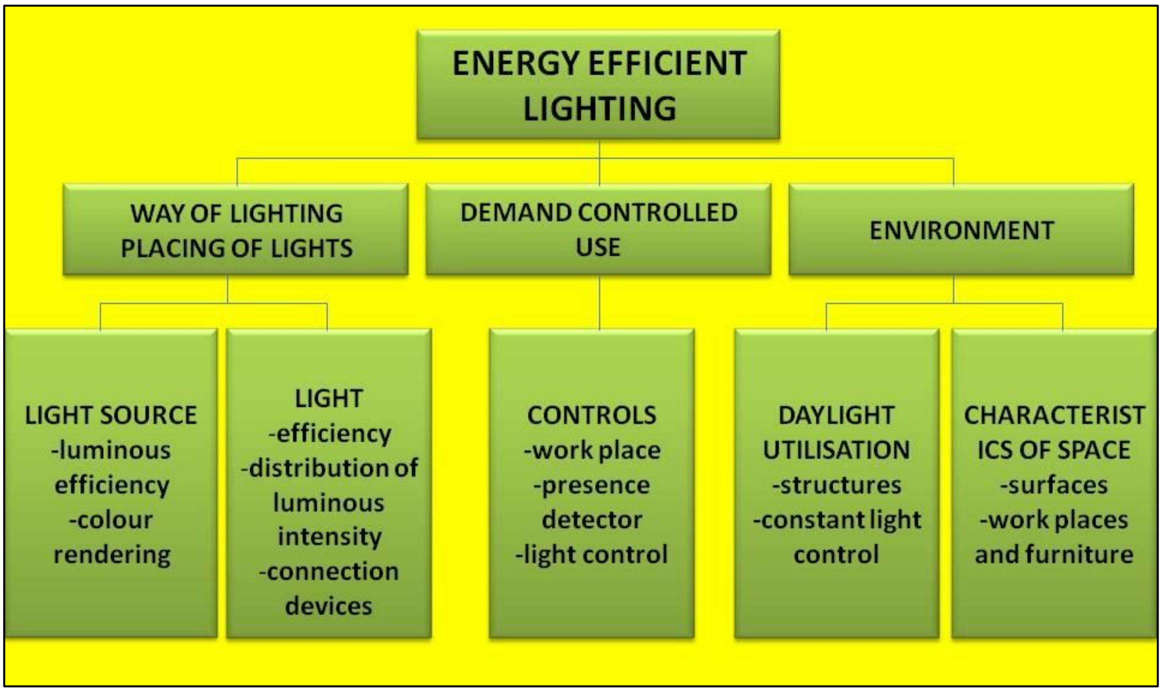


Figure 6 Energy Efficient Lighting (Kallasjoki, 2011)

The starting point for the design of lighting is the need for lighting and the characteristics of spaces (Holopainen, et al., 2007). Daylight should be utilised whenever it is possible (Soininen, 2009). The saving potential achieved by the daylight is approximated about 30-60 % and it is dependent on the frame of a building (Holopainen, et al., 2007). However the central zones of open offices, which are at a distance from windows, are not benefitted from the daylight (Korhonen, et al., 2002).

The power densities of lighting in offices are about 10-15 W/m^2 nowadays depended on the lamp types and how much the indirect lighting is used. Lights should be switched off always when a property is not occupied and fluorescent lamps are profitable to switch off when they are not needed over 10 minutes. The energy saving based on switching off is directly proportional to the electric power of lighting. (Tetri, et al., 1996)

In offices, the important factors when limiting the unnecessary energy consumption of lighting are presence detectors, time switches and control. In addition, old lights can be replaced by more efficient and the newest types of fluorescent lamps. One way of saving in energy consumption is a transfer to a located general lighting or a combination of faint general lighting and local lighting. (Holopainen, et al., 2007).

3.4 Existing Building Commissioning

Consumption monitoring is a prerequisite for target-oriented energy management. Programmes for energy consumption (electricity, heating, water) monitoring have been developed to enable simpler monitoring and easy comparing in different ways. Usually comparing is made to the previous year or between the same types of buildings. (Ahonen, 2001). The essential concept which is related to monitoring and targeting is existing building commissioning (EBC). EBC is also known as retrocommissioning that applies to a systematic investigation process for improving and optimizing operation and maintenance (0&M) of a building. (Haasi & Sharp, 1999).

The base of EBC for improving energy performance is consumption audits of the building and analysing the energy consumption results with regularity. The best solution is to have at least monthly consumption reports and in larger buildings, such as in office buildings, it is good to have also under metering systems to monitor the most important partial consumptions. Utilising available computer based consumption monitoring systems already just following up the bills; EBC can be done with a small effort and marginal costs. (Pietiläinen, et al., 2007)

Monitoring the realised consumption of a building (heating, electricity and water) and comparing it with earlier similar information, energy efficiency can be continuously evaluated. In this way, differences can be easily observed and reasons for them can be determined. (Pietiläinen, et al., 2007). The target value of energy consumption of a building can be also defined for example by energy simulation and the calculated value can be compared with the realised consumption. In this way, the potential energy saving targets and the reasons for the high consumption can be easily charted. The features that can be measured and simulated in addition to energy consumption are, including temperatures, ventilation rates, internal heat gains, user profiles and timetables. (Kalema & Pylsy, 2006). However, the calculated energy consumption and measured consumption can be far away from each other because there are many X-factors in the calculation, such as ventilation rates and operation periods. (Pietiläinen, et al., 2007).

3.5 Environmental Assessment Tools for Existing Buildings

Environmental assessment tools for buildings have been developed so that investors, authorities, owners and users can compare buildings and constructions projects by integral methods (GBC Finland, 2012). The environmental assessment tools support taking the environmental aspect into account in design and construction process and in the maintenance of a building. With environmental assessment tools, environmental goals, controlling their fulfilment and documentation is ensured. (Reinikainen & Dooley, 2008).

Different tools have been developed to measure different types of buildings, such as new and existing buildings, residential buildings and office buildings. Different tools use different criteria in the environmental assessment of a building. (Haapio, 2008). Different criteria can have different weights. Criteria are typically divided in the main classes that are:

- Energy efficiency;
- Indoor climate and healthiness;
- Construction site;
- Construction materials;
- Water use; and
- Systematic management.

A total grade is determined on the weighted sum of different grades. (Reinikainen & Dooley, 2008). In Finland, the most used building environmental assessment tools for existing buildings are LEED Operations & Maintenance and BREEAM In-Use. In addition, Finland has its own environmental assessment tool for existing buildings called “Kiinteistö-Promise” but it is not as widely in use as LEED and BREEAM. (Reinikainen & Dooley, 2008).

BREEAM (Building Research Establishment’s Environmental Assessment Method) is a British environmental assessment tool and has been in use since the year 1990 (GBC

Finland, 2012). According to the amount of certified buildings (250 000) BREEAM is clearly the world's leading building environmental assessment tool. BREEAM In-Use is developed to help building managers reduce running costs and improve the environmental performance of existing buildings. The Part 3 of the BREEAM In-Use is currently restricted to offices. In BREEAM, the given grades are acceptable, good, very good, excellent and outstanding. (BREEAM, 2013).

LEED (Leadership in Energy and Environmental Design) is American and internationally comparable environmental assessment tool. The LEED-certification is admitted by the U.S: Green Building Council and it is based on the independent, third-party verification of spaces, a building or a construction project. LEED for Existing Buildings: Operations & Maintenance was designed to certify the sustainability of ongoing operations of existing commercial and institutional buildings. It encourages the owners and operators of existing buildings to implement sustainable practices and reduce the environmental impacts of their buildings. The certifications are awarded in the following grades: certified, silver, gold and platinum. (USGBC, 2009).

WWF (World Wide Fund for Nature) has created its own environmental diploma for offices, so called Green Office, which concentrates on changing users` behaviour. Green Office motivates office users to act in an environmentally friendly way, improves environmental awareness and brings cost saving. The offices that fulfil the Green Office criteria are given the Green Office diploma and the right to use the Green Office logo. There are already 68 500 offices granted the Green Office labelling rights. (WWF, 2013).

4 GREEN LEASES

This chapter presents an environmentally efficient lease "green lease" and the challenges that complicate its introduction and becoming common. At first, it is studied how the different lease structure influence on applying energy performance measures to an office building. Then the contents and requirements of environmentally efficient lease "green lease" are presented.

4.1 Effect of Lease Structure

Leases can be defined as relationships between the owners, occupiers/tenants and operators of tenanted official buildings (Roussac & Bright, 2012). Energy performance is becoming a higher priority for both tenants and owners as a range of new policy measures, such as EPCs and tightened regulations, begin to impact to both existing and new leases. In addition, the owners and tenants feel increasing environmental responsibly for their properties. (Hinnells, et al., 2006).

Even if the need for reduce environmental impacts is noticed, the structure and content of a lease can prevent and complicate applying energy performance measures to a building. Leases tend to be strictly formed and do not allow flexible responses to new situations. Because the length of leases these problems can continue over substantial time. The leases have to be allowed greater flexibility in order to respond to new demands and maximise the opportunities to decrease the environmental effects of properties. (Roussac & Bright, 2012).

Environmentally friendly measurers cause notable energy and cost savings but who benefits from them depends on the contact type. Traditionally, a gross rent is used in office leases in Finland but also a net rent, which is often used in abroad, is coming more common (Virtanen, 2010). The gross rent also known as total rent includes real estate costs that are caused by the existence of a property. These are capital costs, taxes, insurances and maintenance costs. The capital costs consist of interest rates and calculated depreciations. The gross rent can also include the costs of utilities and the cost of services. (RAKLI, 2001). The owner has a total risk of the rise of the maintenance and capital costs (RAKLI, n.d). In this case, tenants do not have a motivation based on the economic advantage to decrease their consumption because the rent is fixed-price and the benefits of the savings are going straight to the owner. The other problem of the gross rent is related to the furniture and appliances which are paid by an owner but their use is paid by tenants. The owner has no motivation to purchase energy efficient appliances to the rented property because the costs caused by the use are paid by the tenants and the tenants are also receiving the possible savings. (Kuula, 2012).

A net rent includes only capital costs, possible taxes and insurances. A tenant is responsible for the maintenance costs. The contract encourages the tenant decreasing the maintenance costs because savings gather to him. (Virtanen, 2010). The owner has a risk that the tenants are not taking care of maintenance but the risk can be decreased by security. The third way to determinate the rent is a divided rent. It consists of capital rent, maintenance rent and other parts of the rent. (RAKLI, n.d). The aim of the divided rent is transparency when both parties know how the rent is formed (Kuula, 2012). In addition, a separate maintenance rent encourages tenants to attend more the cost caused from their operation and to decrease their consumption. (RAKLI, n.d).

4.2 Contents of Green Lease

There is a number of ways how leasehold contracts can be structured and managed to promote environmentally better use. The commonly called definition for an environmentally lease is “green lease”. (Hinnells, et al., 2006). The contents of the Green Lease can relate to any or all of energy use, water management, waste disposal, travelling and the use of sustainable materials. (Roussac & Bright, 2012).

The Green Lease model should be formed so that energy consumption and it price has importance to both an owner and tenants. It should create economic incentives for both parties of the contract to behave in an environmentally way and improve energy efficiency. In addition, the owner and tenants should have enough knowledge about energy issues. (Kuula, 2012). In one case study (Huhta, 2010, p. 42) the most important elements of the Green Lease of an office building were identified:

- energy consumption
- used forms of energy
- indoor air quality
- waste management.

To manage energy consumption, the influence of contracting parties on all the energy consumption of a property have to be recognised and after this the cost liability has to be divided according to this. The inside temperatures have a significant effect on heating and cooling energy consumption so to manage these consumptions the inside temperatures and their tolerances should be agreed in the lease. Energy consumption should also be possible to accurately measure so that the equitable cost distribution could be realised. Therefore the notable investments should be done on the systems of measurements and the parties should be clearly agreed on the practices of reporting. (Huhta, 2010, p. 42).

One noteworthy challenge in Green Leases is the users that are not tenants themselves but the employees and staff of the tenants. In this situation, the users usually do not have access to a copy of the lease or an awareness of the responsibilities of the owner or tenant.

The innovative approaches should be adopted within leasing practices that take into account how occupiers behave and what occupiers want out of buildings. (Hinnells, et al., 2006).

5 BUILDING INFORMATION MODELLING (BIM) OF EXISTING BUILDING

This chapter presents the contents of building information modelling (BIM) and the ways of building information transfer and problems related to them. It is described how BIM can be utilised in energy analysis and what kind of requirements are needed for the model.

5.1 Building Information Modelling (BIM)

In the current building design, there has been increasingly discussion about Building Information Modelling (BIM). BIM has been developed as a definition and a complex when the knowledge of building trade has been increased, regulations have been tightened and working tools have been developed. BIM has woken various wishes, believes and even prejudices. (Penttilä, 2009). The major barriers that have prevented BIM becoming common are the change opposition of the building trade, the learning costs of the transitional phase and the compatibility problems of software applications (Ropo ry, 2013).

The most common definition for BIM is a file that is created by the use of three-dimensional computer-aided design (CAD). BIM can be also described as a process enhancement methodology that leverages data to analyse and predict outcomes throughout the different phases of a building life cycle. (Reddy, 2011). BIM can take many forms: it can be a simple temporary model created for a specific purpose, such as building services design or a shared 3D-whole building model containing architectural, structural, servicing and other data in the same place, so called “full BIM”. In new construction, the development is going more towards the full BIM, which enables developing shared models, more consistent and coordinated designs, less misinterpretation, disturb and re-work. Figure 7 presents the elements that the full BIM can consist of. (Langdon, 2012).

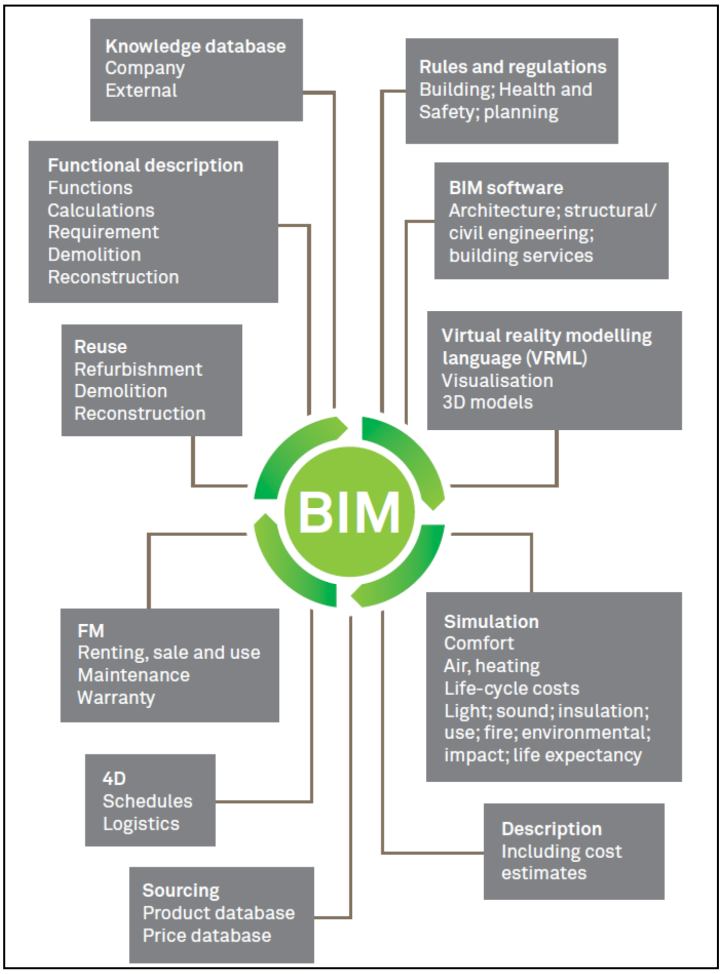


Figure 7 Full BIM (Langdon, 2012)

The model based energy simulation is one of the most important purposes of use where BIM brings a significant improvement compared with traditional principles. When the energy simulation is already realised in the early phase, the cost-efficient solution can be found ahead of time before the final construction plans are ready. BIM operates as a base for the simulation model and the realised design solutions can be updated to the BIM models. The created simulation model can be also utilised during the operation and maintenance. The BIM- based energy analysis is studied more in chapter 5.3.1. In addition to energy simulation, BIM offers an opportunity to investigate the optimum solutions for different lightings, shadings and temperatures. By this function, it is possible to achieve the LEED points related to indoor air quality. (Ropo ry, 2013).

5.2 Building Information Transfer

5.2.1 Creating Information

The digital project model is typically created by software using “object” technology. Objects are digital representations of the parts of buildings. In general, these are physical components, including doors and windows, but they can also be more abstract entities such as spaces. Different software providers used to have their own methods of defining and handling objects therefore their systems and information contained within them were not interoperable. Interoperability and the effective exchange of information between different software applications such as architectural and structural engineering CAD systems play a key role in BIM (Langdon, 2012).

Information is stored the best and most completely in the original data format of software, for example AutoCAD drawings in dwg-format. Instead, when the information is saved in another format, some information is always lost (Penttilä, 2009). The BIM-based process currently involves various products and technologies and therefore there are limitations in the process of transferring information from BIM to other software applications. A significant problem is that BIM applications do not support many of the information exchange requirements such as occupant and HVAC schedules which are needed for energy analysis. The current export of building information to data models is imperfect, does not provide a reliable source of geometric data and must be manually modified and improved to carry out successful energy calculation. (GSA, 2012). Building information modelling in energy analysis is discussed more in chapter 5.3.

The data formats that are frequently used IFC and XML create a common language for transferring BIM information between different BIM and building analysis applications and maintain the meaning of the different pieces of information in the transfer. They reduce the need for remodelling the building in each different application and add transparency to the process. (GSA, 2012).

5.2.2 Industry Foundation Classes (IFC)

Industry Foundation Classes (IFC) is developed by the International Alliance for Interoperability (IAI); it provides standard ways to define information contained in BIM. IAI developed object-oriented data model IFC to describe the relationships and properties of building specific objects. IFC is an object-oriented data model that describes the behaviour, relationship, and identity of a component object within a model. (GSA, 2012). IFC is an open and independent format. It can be used be used to exchange and share BIM data between different software applications without the software having to support numerous native formats. (BuildingSMART, 2013).

Figure 8 presents information exchange between two different software applications A and B. Both software read and save in its own data formats and in neutral IFC, so in this case the IFC is the only way to exchange information between these two software applications. (Penttilä, 2009).

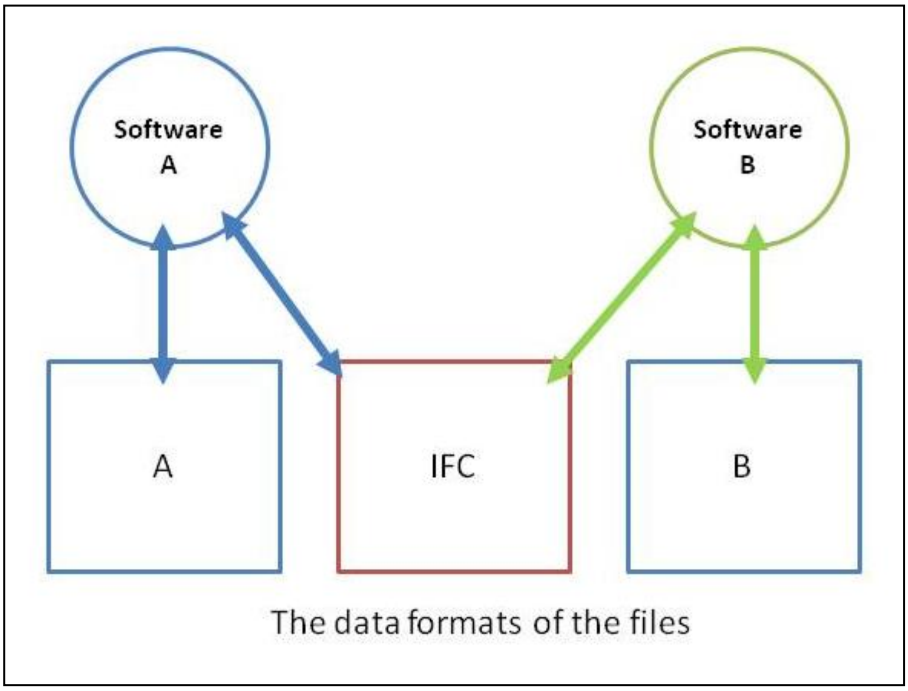


Figure 8 Information Exchange by IFC (Penttilä, 2009)

5.2.3 Extensible Markup Language (XML)

Extensible Markup Language (XML) provides standard ways to define information contained in BIM. XML is a set of rules designing formats for structure information. It is the result of the popular HTML code used to develop Web pages. XML supports data transaction between different software applications to a better way to communicate information. Several industry-specific XML-based schemas are currently being developed for the building industry, such as green building XML (gbXML) and ifcXML that are the most relevant to building performance analysis. (GSA, 2012).

The gbXML schema was developed by Green Building Studio (Dong, et al., 2007). It allows a detailed description of a building for the purposes of energy and resource analysis (GSA, 2012). The IFC has the capacity to represent any shape of building geometry while gbXML only accepted rectangular shape that is enough for energy simulation. GbXML schema is also simpler and easier to understand than IFC that enables the faster implementation of schema extension for different design purposes. (Dong, et al., 2007). The gbXML allows for data interoperability between complicated BIM applications and building analysis programs. It is the most broadly supported data format for the exchange of building information between BIM/CAD and energy performance applications. (GSA, 2012). Furthermore, there is a data format called IfcXML. It is IFC Model that uses XML schema language. IfcXML enables the exchange of IFC product data in XML format (Karstila, n.d).

5.3 BIM for Energy Analysis

5.3.1 BIM-Based Energy Analysis

Energy consumption in buildings is the outcome of a complicated set of relations between the external environment, the shape and character of building components, equipment loads, lighting, mechanical systems, building envelope, and air distribution strategies. Achieving the greatest possible energy efficiency requires an understanding about these relations and the integrated “whole building” design process. Building energy simulation is a method for analysing the energy performance of buildings to estimate the thermal impacts of various design options, and to develop an effective building form and design strategies. Simulation results provide information on building energy consumption and utility costs, indoor environmental conditions, and thermal comfort. (GSA, 2012). In existing buildings, energy analyses can be utilised to analyse energy performance and ensure that the realised energy consumption is near the optimised situation (Sinisalo, 2012, p. 47).

Energy simulation tools usually consist of a graphical user interface and a thermal calculation engine that requires the input data presented in Figure 9. (GSA, 2012).

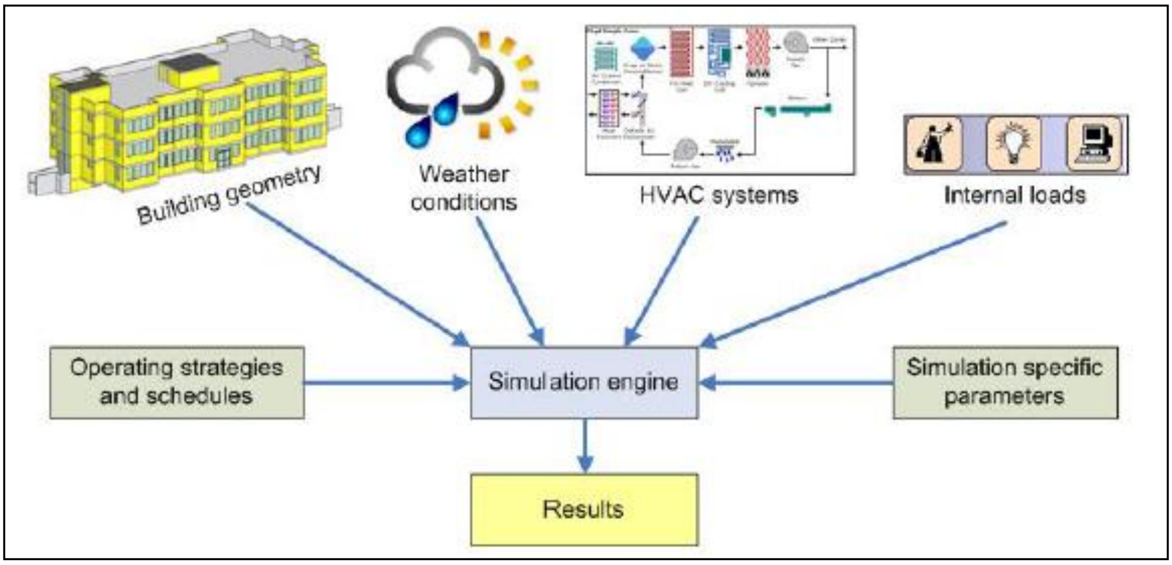


Figure 9 General Data Flow of Simulation Engines (GSA, 2012)

Energy simulation is performed as an annual hourly calculation where the building loads and the system capacities required to meet these loads are calculated. A thermal calculation engine is based on thermodynamic equations, principles, and assumptions which attempt to predict the actual thermal processes occurring in a building. Energy modelling uses information from drawings, specifications and other project data available. The energy model is created using either a graphical user interface (GUI) to the simulation engine or by creating in input file directly using a text editor. All required parameters, such as space loads and HVAC systems, are input directly or using a GUI. (GSA, 2012).

The main barrier of the wider usage of energy simulation tools has been the massive manual input work which is required (Laine & Karola, 2007). When BIM is utilised as a data source for energy analysis, the model has not manually recreated or modified which is experienced to be time-consuming and demanding. The geometry of BIM-based energy model can be generated directly from pre-existing BIM files. Moreover, input assumptions can be easily assigned to the space themselves which allow for greater specificity and accuracy. The BIM-based energy analysis saves time and makes the process simpler. (GSA, 2012; Laine & Karola, 2007).

When EPCs recently changed to be based on the calculated energy performance instead of the realised consumption, the use of energy analyses is coming to increase significantly. This leads also for the fact that the utilisation of building information models is coming to increase to support the energy analysis of existing buildings. Moreover, BIM can be utilised when a difference in energy consumption is noticed and reasons for that are charted. The possible error situations and the differences in the change of use can be also excluded by way of BIM. (Sinisalo, 2012, p. 47).

5.3.2 Information Exchange Requirements

Finnish Senate Properties in the cooperation with BuildingSMART and several other real estate owners and developers, construction companies and software vendors published Common BIM Requirement 2012 (COBIM). COBIM is based on the previous instructions of the owner organizations and the users' experiences derived from them. The minimum requirements for modelling and the information content of models are presented in COBIM (2012). The requirements of information models used in energy analyses are defined in Series 10: Energy Analysis of COBIM (2012).

In COBIM: Series 10, there are no requirements for energy analysis in the operation and maintenance of a building, in other words there are no requirements for the existing buildings. However, the energy analysis can be used to investigate that a building operates according to the targets. By energy analyses, the effects of the changes occurred in the operation can be updated to the targets. In addition, energy analyses can be utilised in malfunctions and resolving them and comparing repair options. (Laine, et al., 2012).

The energy analysis process and the information exchange requirements are presented in Figure 10. There are no requirements for the results of spatial air-conditioning and the results of energy and comfort but it is recommended that their information exchange is BIM based. (Laine, et al., 2012)

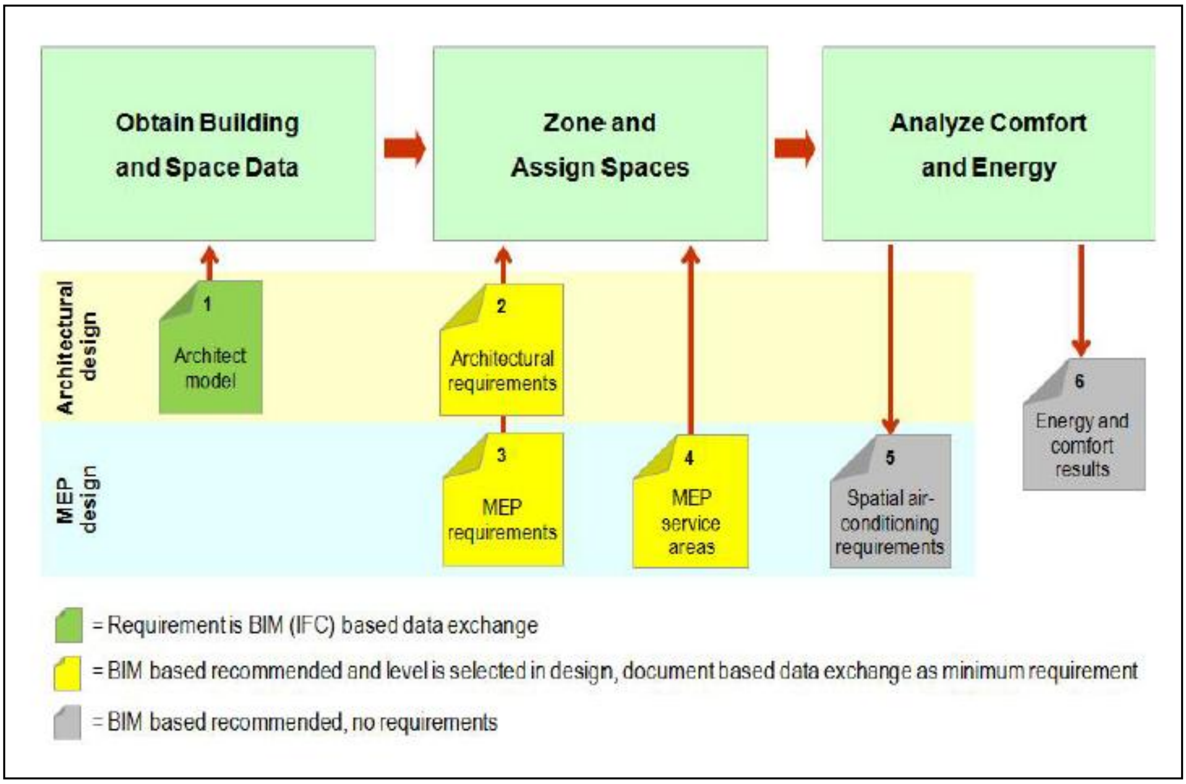


Figure 10 Information Exchange Needs and Requirements for Energy Analysis (Laine, et al., 2012)

The most important initial data in energy analysis is architectural BIM. The data is required to include the following views defined in the IFC standard:

- Coordination view for collaboration between the architect, structural designer and MEP (mechanical, electrical and plumbing) designer

- Space boundary add-on view which defines space surfaces and their connection to other elements, such as structures and openings.

If architect's model has been created in BIM format, it will be possible to utilise it in an energy analysis program. If it is not possible to generate an architectural BIM that fulfils the requirements, a separate geometry model can be created that fulfils the above mentioned requirements. In this case, the space names and codes used in the architect model are kept unchanged. The target and service area information on MEP system have to be transferred as a document to support the initial data needs of energy analysis. If MEP target information and service areas have been defined based on BIM, they can be utilised in the energy analysis program. (Laine, et al., 2012).

6 CASE STUDY

The aim of this chapter is to study what sort of energy efficiency services enable by BIM would serve the tenants of the case building. The research strategy is a single case study that consists of the semi-structured theme interviews of the tenants of the case building and energy simulations based on the light BIM of the case building.

6.1 Case Description

The object of the case study is a multitenant office building called "Hakaniemenranta 6" in Helsinki, owned by Senate Properties. The building was constructed in 1975 and fully renovated in 2008. In the renovation, a parking space was constructed under the yard level. Service spaces, educational facilities, and other public spaces are centralised on the ground floor. In addition, there are six office floors and a roof floor with a sauna department. The area of the office building is about 23 000 brm^2. (Senate Properties, 2008).

6.2 Research Material and Methods

The research strategy was a single case study. In a case study, the aim is to produce detailed information from a chosen case (University of Jyväskylä, 2013). The research materials of this case study were theme interviews and the existing documents of the case building. The theme interview was divided into themes that had been prepared from the theoretical framework of the study. The theme interview was semi-structured. All the respondents were given the same open questions that had no ready answers. (University of Jyväskylä, 2013). The answers were analysed in themes. The existing documents of the energy calculations were the two dimensional space model of and the light BIM of the case building and the energy efficiency plans of the offices that operate in the case building. These documents are reviewed more in chapter 6.4

6.3 Interviews

6.3.1 General Info and Interview Questions

Theme interviews were arranged in the case building at the end of June 2013. Five representatives of the office tenants were interviewed:

▪ Specialist in the national agency subordinate to the Ministry of Education and Culture;

▪Deputy Director in the independent, private, not-for-profit service organisation that specializes in cultural exchange;

▪Chief Agency Supervisor in the national agency subordinate to the Ministry of Education, Science and Culture:

▪Senior Programme Adviser in the organisation for international mobility and cooperation; and

▪Chief in the restaurant.

The interviewed tenants are part of the energy management group of the property that consists of people who are responsible for the energy issues of offices. The aim of the group is to plan development ideas related to the energy use of the property. The group was initially formed to planning the measures for the energy saving week in autumn 2012. Since, the operation has been continued with the users' electricity project and other energy issues.

Themes of the interviews were:

A. Energy efficiency of office buildings
B. Green Office
C. Thermal conditions
D. Energy Performance Certificates
E. Green Leases
F. Tools for improving energy efficiency

The first theme studied office tenants' energy efficiency targets and realised energy efficiency measures. In addition, the awareness of factors influencing the energy efficiency of an office building was investigated. The second theme studied the use of Green Office service and its benefits and operational influence. The third theme investigated tenants' satisfaction to the thermal conditions and their opinion about building automation. The aim of the fourth theme was to study the knowledge and opinion of tenants about EPC. The purpose of the fifth theme was to investigate the interest of tenants in Green Lease models. Their awareness of the lease content was investigated and their interest in influencing on it. The aim of the sixth theme was to study indicators, reporting and services related to energy efficiency, tenants would be interested in. Moreover, the knowledge of tenants about the existing consumption metering systems of the building was investigated. The used interview questions are presented in Appendix 1.

6.3.2 Results

A. Energy Efficiency of Office Buildings

In the interviews, it revealed that the tenants of the case office building are quite progressive in energy issues. Three of the offices have made an energy efficiency plan in 2012. The energy efficiency plan is based on the decision in principle of the Council of State to improve the energy efficiency of the public sector. The energy efficiency plan consists of the energy use of properties, electricity use, commutation and other energy use, such as appliances. (Motiva, 2013). One of the offices is the subtenant of another office, so it observes the same energy efficiency plan as the main tenant. The service provider is a restaurant and has its own environmental program. Moreover, one of the offices has a group that focuses on sustainable development, and hence it contributes the energy efficiency plan by its operation.

Due to the energy management group the tenants have been more aware of the operation of others and cooperation has increased. The tenants regarded the electricity consumption to be the most important factor affecting the energy efficiency of an office building. In the restaurant, the most important factors were the energy efficiency of appliance and their correct use. One of the interviewed tenants regarded that the technical design solutions made in the building have the major effect on the energy efficiency. In the opinion of the interviewed tenants, the energy efficiency measures tenants are responsible for, are informing the users of energy use and purchasing energy efficient appliance.

The common energy efficiency measures realised in the office spaces were:

- replacing old workstations with new energy efficient laptops;
- introduction the powersave modes of office devices; and
- informing the users of energy efficient behaviour.

One of the offices keeps the corridor lights off in summer. Another office also tried the same but the users felt it too dark so they returned to the former. The most of the users of the office building seem to be obeying the given rules for the energy efficient behaviour.

However, for some users the rules are insignificant because they are not responsible for the energy expense. In addition, it appeared that the tenants are aware of different energy efficiency measures but they do not know their effectiveness. For example, they were uncertain if the electricity consumption has been decreased after the implemented measures. One of the tenants commented that the effects of the measures show too slowly to tenants.

There has been a lot of discussion between the tenants and the owner, Senate Properties, about the energy issues of the building. The case building is a part of the user electricity project of the Senate Properties which pursues decreasing electricity consumption in their properties. The project has been implemented by affecting the electricity use of users by briefing and including users in actions. The control of the house services has also been improved. (Senate Properties, 2013). In addition, other shared projects were an annual energy saving week and the monthly meetings of the service management group about energy consumptions (electricity, heating energy, water, waste) of the building.

B. Green Office

One of the offices has the Green Office Diploma and therefore their undertenant and the restaurant operating in the building also obeys Green Office rules. The diploma is also this year’s aim of one office and they already operate according to the rules of Green Office. The effects of Green Office in the offices were according to the interviewed tenants:

▪ minimized paper consumption;
▪ all the workers have their own ceramic cups;
▪ energy efficient laptops;
▪ increased possibilities for telecommuting and teleconferences; and
▪ improved collection and sorting of waste.

C. Thermal conditions

The interviewed tenants were mostly satisfied with the thermal conditions in the building but some dissatisfaction has been noticed. The indoor air quality has been measured in some of the spaces but nothing notable was found. The noticed problems were:

▪ Thermal conditions, particularly the temperature, vary in the different sides of the building.

▪ There is inadequate ventilation (stuffy air) in part of the floors.

▪ The smell of a sewer has been noticed in one of the staircases.

The tenants had different opinions on the control of thermal conditions. Two of the tenants favoured that users can control themselves conditions because the working times of the different users vary so much. As against, the one of the tenants favoured automatic control because she thought that the general settings are suitable for the most of the users. Moreover, one of the tenants preferred “hybrid model” where users can control themselves conditions but when the building is unoccupied the automation controls conditions. According to his words, the automation should consider the utilization of natural light and current outside weather conditions.

Two of the interviewed tenants considered the automatic control of lighting difficult because users cannot turn all the lights off if they want. For example, the open-plan offices and the restaurant have personal lights with pulling couplings. The tenants considered those handy to avoid the unnecessary use of lighting. However, the problem was that they did not know how to turn those all off with one main switch.

D. Energy Performance Certificates

The interviewed tenants were heard about EPCs mainly from the news and papers. The content of the new EPC was not obvious to the tenants.

The tenants liked EPC due to its clear form and its possible influence on expense:
“EPC is a profitable tool and it is interesting to know the cost-effective measures to improve E-value.”
“The lower the E-values is, the lower the maintenance rent should also be.”
“The form and appearance of EPC is clear and short. The cover page, particularly, is the most interesting for tenants.”

EPC was found profitable in long leases and when a lease is in the end:
“In long leases it will be interesting to know measures that improve E-value if the paypack time is not too long.”
“EPC is the most useful when a lease is in the end and tenants have to decide whereas to stay at the old premises or change to the new one.”

However, the matter that tenants cannot influence on the given E-value by their behaviour reduced the value of EPC for the interviewed tenants. One of the tenants supposed that the influence on the energy expense in different energy performance ratings could be present in EPC. In addition, the tenants viewed valuable that the energy performance measures related to user behaviour are presented in EPCs.

E. Green Leases

The current rents of the case building are determined according to rented areas. Heating and water consumptions and waste management are included in the rent. The electricity is separately paid by the tenants. The interviewed tenants thought that if the behaviour had an effect on the amount of the rent, it would increase the motivation of tenants for energy efficient behaviour. The Green Lease model was not familiar to any of the tenants.

The benefits of the Green Leases according to the tenants were:

▪ Tenants' motivation for energy efficient behaviour would increase.
▪ Tenants would think more about the consumption; what is necessary and what is not.
▪ The idea of paying only for what is consumed was considered good.

The challenges of Green Leases according to the tenants were:

▪ Investigating the realised consumption and focusing the consumption costs for different tenants were considered difficult.
▪ The need for extra consumption metering was recognised and it was considered expensive.
▪ Tenants begin to save in wrong areas in the hope of refunds in consequence that the working conditions of end-users would be decreased.
▪ The maintenance of Green Lease would increase bureaucracy and work, particularly to the service manager of a tenant.
▪ End-users are indifferent to their consumption because they are not paying the rent and therefore the rent is increased.

All the interviewed tenants thought that their office could adopt the Green Lease model if the model was workable and the expense were based on the realised consumption.

F. Tools for Improving Energy Efficiency

The interviewed tenants were partly aware of consumption metering in the building. Senate provides reports about electricity, heating, water and waste consumption. The electricity consumption is only which is followed per a tenant and other consumptions are calculated by rented areas. The tenants were mainly observing their electricity consumption as they can impact the most on that. Analysing the electricity consumption reports was considered complicated because the tenants felt problematic to discover the reasons for the changes in consumption. The tenants were interested in separate metering systems for different offices but were afraid of investment expense.

The interviewed tenants were attracted to the readily understandable and compact reports of energy consumption. They do not have time nor interest in applying to long and complicated reports. The reports should cover only the issues that have a concrete benefit to tenants. The content of the report should be ready analysed by an expert and it should include the proposals for improvement. According to the tenants, users will not know how to make improvement without concrete advice.

The content of reports the interviewed tenants were interested in:

▪ differences between floors and organizations;
▪ quantities related to the indoor air quality;
▪ the effect of behavioural change to energy consumption
▪ the cost saving of changes; and
▪ values based on the real consumption.

The energy efficiency services the interviewed tenants were interested in:

▪ the energy consumption indicator of a working place and
▪ services that support users in behavioural change.

<u>Key findings of the thematic interviews were:</u>

▪ All the tenants had energy efficiency targets and realised energy efficiency measures.

▪ The tenants were aware of energy efficient behaviour and the most of the tenants were obeying the rules of Green Office service.

▪ The tenants were mostly satisfied with the thermal conditions apart from the dissatisfaction to the temperature and inadequate ventilation in part of the building.

▪ The tenants had no common view of building automation systems.

▪ EPC was found a profitable tool, particularly in long leases and when searching for new office premises. The tenants found as a shortage that they cannot influence on the given E-value in EPC by their behaviour.

▪ The Green Lease model was not familiar to the tenants but all the tenants would be interested to adopt the model in their organisation if it was easily realisable.

▪ The tenants wanted to have the readily understandable energy consumption and indoor air quality reports of which content is ready analysed and the proposals for improvement are included.

6.4 Energy Calculations Based on Light BIM

6.4.1 Creating Light BIM

In this study, a light BIM refers to a BIM that only consists of required information in adequate accuracy to investigate the energy performance of a building. The light BIM can be created by two different methods:

1. Based on 2D Space Model

An existing 2D space model consists of a building area, space types and their boundaries and the number of people. The 2D model is modified to an IFC-file and the information content is imported to an energy simulation application where the model is lifted up to a 3D model numerically by adding walls, storey heights and the percentage of windows. Other required initial data of the calculation is entered numerically.

2. Based on Architectural Drawing

The 2D model of the building is modelled based on an existing architectural drawing. The created 2D model is modified to an IFC file and the information content is imported to an energy simulation application. In the energy simulation application, the model is lifted up to a 3D model numerically by adding walls, storey heights and the percentage of windows numerically. Other initial data of the calculation is entered numerically.

In the method 1, the modelling work is reduced notably due to the existing 2D space model is utilised and other data is entered numerically. In this study, the information content of Optimaze space model is utilised. Optimaze.net is a service developed by Rapal Oy. It is designed to help manage premises and comprehensively administer property. For the users, the service produces information about space utilization and costs to support decision-making and generates savings by optimising space utilisation. (Rapal Oy, 2013).

If a light BIM is created only based on the information content of an Optimaze file or other 2D space model, some of the required initial data is missing and should be determined to achieve reliable results from energy simulation. The initial data given in an Optimaze space model and initial data that has to be determined is presented in Table 7. The missing initial data is possible to determine based on a type or construction year of a building to decrease the work. However, when the initial values are based on tabular values and are just estimated, the reliability of energy simulation results is reduced.

Table 7 Initial Data of Energy Simulation

Initial data	Optimaze space model	Required
Building area	x	
Number of people	x	
Space types and areas	x	
Utilisation rates		x
Storey height		x
Windows		x
Construction types		x
Infiltration rate		x
Air conditioning space groups		x
Heat recovery efficiency		x

6.4.2 Initial Data of Energy Simulation

The light BIM of the case building was created when the building was renovated in 2009. Therefore, the creation phase of a light BIM was not investigated in this study, only the opportunities and services that the energy simulations of a light BIM enable. The light BIM of the case building was based on an architectural drawing and other design values.

The available model was more accurate compared to the one created by the methods in chapter 6.4.1 as the walls and windows were modelled not entered numerically.

The light BIM was in IFC form from where the geometry information was red to the Riuska energy simulation application. Riuska is developed by Granlund Oy and it uses BIM to calculate the thermal conditions of a building and its spaces in different loading and weather conditions. Riuska supports just IFC formats, for example Riuska supports no gbXML. (Granlund Oy, 2013). The available Optimaze space model of the case building was utilised to modify and update the existing light BIM in Riuska application. For example, the current space types and their boundaries and the number of people in the spaces could be updated utilising the information content of Optimaze. The geometry model of the case building is presented in Figure 11.

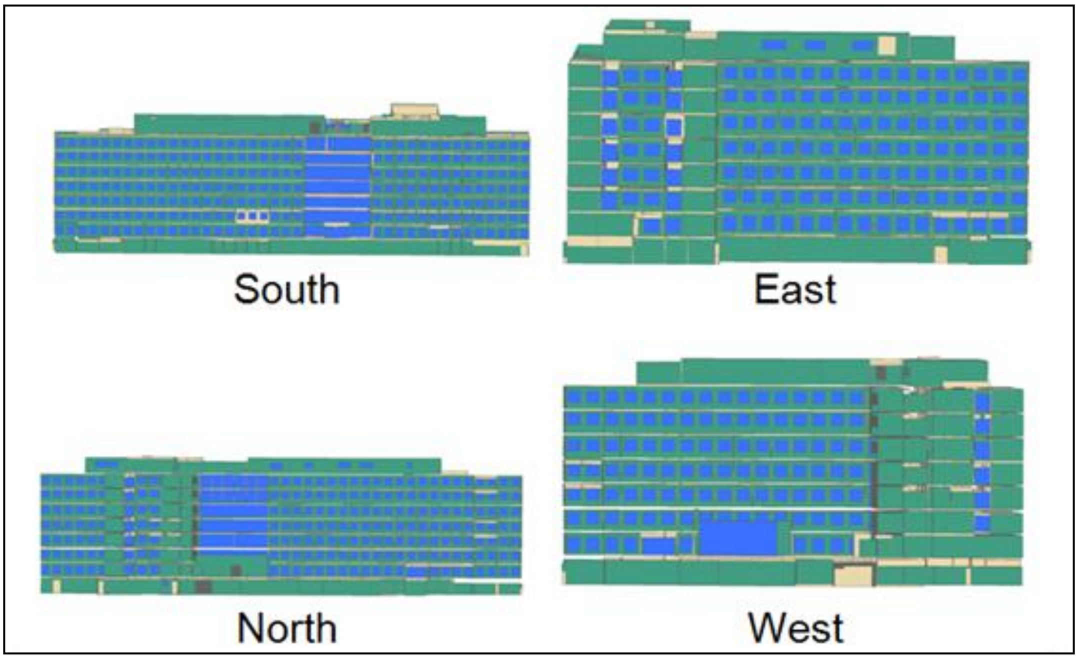


Figure 11 Light BIM of Case Building (Riuska Simulation Application)

The case building is mainly in use from Monday to Friday 8-17. The main inside temperature of the building is 21 °C; the setpoint temperature of the cooling is 23 °C and the rated temperature 26 °C. The temperature of the garage is 15 °C. The average value 0.14 l/h has been used as an infiltration rate. The next U-values were used in the calculations:

▪external wall 0,24-0,25 W/m^{2}K

▪ base floor 0,29 W/m^{2}K (ground slab)

▪ roof 0,16 W/m^{2}K

▪ windows 1,09-1,39 W/m^{2}K

The technical values of the windows are presented in Table 8. The glass part and the frame are included in the U-value of the window. In the MSE windows of the office spaces have blinds that were assumed to be used when the sun shines to the window heavily enough. The use of blinds has been simulated so that a half of the area of the windows is shadowed when the radiant flux coming inside through the window is over 50 W/m2. There are no blinds in other windows.

Table 8 Technical Values of Windows

	G-value*	U-value (W/m^{2}K)
Wooden windows	32,0	1,09
Steel windows	29,5	1,22
Glass partition	32,3	1,39

* G-value= Total solar transmittance, SHGC

The building is provided with a fan assisted balanced ventilation system. The supply air units of the office spaces have a filtration, a heat recovery, heating and cooling. There is no cooling in the parking spaces and in the other cellar spaces. The heat recovery is mainly provided with rotary heat exchangers with the nominal temperature efficiency of 75 % and the annual efficiency of 70 %. The nominal temperature efficiency of liquid heat recovery systems is 50 % and the annual efficiency 45 %. The nominal temperature efficiency of the plane heat exchangers of the restaurant is 60 % and the annual efficiency 50%. In all the cooled spaces, has the night cooling in use in the summer.

Energy simulations were implemented by Riuska application. There were two targets of the energy calculations:

1. Calculate the E-value of the case building and investigate measures that answer the requirements of renovations in the decree (2013/4).

2. Calculate the energy consumption of one tenant in the current use and investigate if the energy efficiency goals are achieved.

5.4.3 E-value Calculation

E-value calculation was made according to the instructions given in the decree on EPC (2013), in NBCF D3 and D5 of year 2012. The energy forms used in the building were:

▪ Heating: District heating

▪ Cooling: District cooling

▪ Electricity: Local electric network

▪ No renewable on site energy

The initial data used in E-value calculation were the values of the standard use of an office building presented NBCF D3 and the technical solutions according to the existing light BIM which are closely presented in Appendix 2. In the calculation, the technical solutions differing from the standard use of D3 were next:

▪ The presence detectors of lighting (mo-fri 7-19)

o Corridors, lobbies, meeting rooms, social spaces and project rooms

▪ Smaller lighting power

o Corridors, lobbies, kitchen, kitchenette, restaurant (10 W/m^2), garage (5 W/m^2)

▪ Variable air volume

o Meeting rooms, auditorium, restaurant, kitchen

In the E-value calculation, heat bridges were taken into account. Riuska application calculates the effects of the heat bridges automatically from the model, when the values are given conductions (Table 9). Riuska calculates the lengths of the heat bridges but those can be also fed manually.

Table 9 Heat Bridges

	Conduction W/(m·K)	Length m
External window joint:	0,20	
External door joint:	0,20	
External wall and roof joint:	0,08	
External wall and intermediate slab joint:	0,00	
External wall and ground floor joint:	0,24	
External wall with a corner pointing outwards:	0,10	0,0
External wall with a corner pointing inwards:	-0,10	0,0

OK Cancel

The calculated E-value for the case building was 163 kWh_E/m^2. To base on this value the building belongs to the energy efficiency rating C. The E-value should be reduced 26 % to achieve the energy efficiency rating B (81-120 kWh_E/m^2). The specification of the E-value is presented in Table 10 and the percentage distribution of the purchased energy consumption is presented in Figure 12.

Table 10 E-value Results

Primary energy	Purchased energy MWh	Primary energy factor	MWh	Primary energy factor weighted energy kWh/m²
District heating	2 139	0,7	1 497	69,6
District cooling	107	0,4	43	2,0
Electricity	1 159	1,7	1 970	91,6
Renewable	0	0,5	0	0,0
Fossil	0	1,0	0	0,0
E-value				**163**

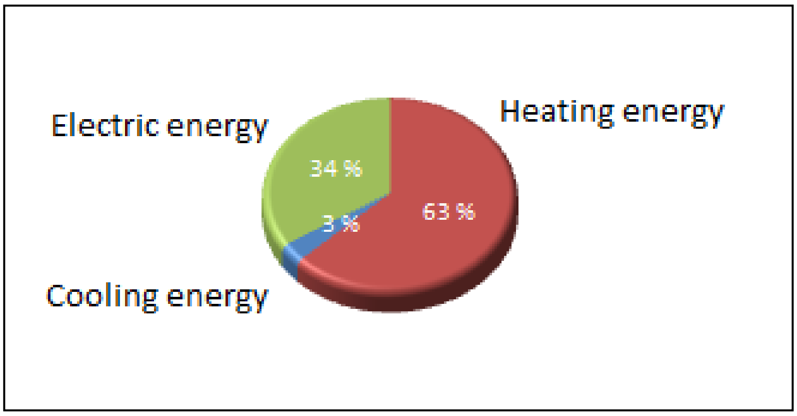


Figure 12 Purchased Energy Distribution in E-value Calculation

The different energy efficiency measures were simulated by Riuska application to demonstrate if the requirements of the decree of renovations (2013/4) are achieved. The first way in the decree is to improve insulation or air tightness to the value in agreement with the requirements. In this case, it was tested to add so much mineral wool that the U-value of the roof would be 0,09 W/m^{2}K and the other tested measure was to decrease the air leakage value to the required level 4 m^3/(h m^2). One mentioned method in the decree (2013/4) is to improve the energy performance of technical systems, which was tested improving the supply air temperature efficiency of all the ventilation machines to the value 75 %. Other measures that were tested were adding solar electricity, adding solar heating and halving the lighting power to 6 W/m^2. The simulated measures and their given results are presented in Table 11.

Table 11 Simulated Measures and Their Results

Case	Energy consumption in standard use (kWh/m^2)	Difference %	E-value (kWhE/m^2)	Difference %
Current	**158**		**163**	
Solar electricity 20 %	147	-7,0	145	-11,0
Solar heating 15 %	144	-8,9	153	-6,1
Lighting power halves to 6 W/m^2	152	-3,8	139	-14,7
Air leakage value to 4 m^3/(h m^2)	148	-6,3	156	-4,3
Supply air temperature efficiency 75 %	127	-19,6	141	-13,5
Adding roof insulation to U-value 0,09 W/m2K	158	0,0	163	0,0

The simulations proved that the energy performance of the case building can be improved in different ways to achieve the requirements of the decree (2013/4). The requirements in the case building are already achieved when the roof insulation, the supply air temperature efficiency or the air leakage value is improved to the values of the requirements. If the energy efficiency is improved with one of these measures, there is no requirement for reducing the E-value. However, the energy simulations showed that the roof insulation improvement did not make a significant effect on the E-value. Instead, improving the supply air temperature efficiency or air leakage value reduced also the E-value. The other method in order to meet the requirements for an office building, is to reduce the energy consumption in standard use, to the value 145 kWh/m^2 or smaller. This was realised in the case building by adding solar heating 15 % or improving the supply air temperature efficiency to the value 75 %.

The last method mentioned in the decree is to improve the E-value of a building to the required level. For the case building the value is 0,7 * 163 kWh$_E$/m^2, which is 114 kWh$_E$/m^2. However, the simulations demonstrated that this requirement was impossible to achieve with any of these measures in the case building. The lowest E-value (139 kWh/m^2) was calculated when the lighting power was halved to 6 W/m^2. It might be possible to achieve the E-value requirement (114 kWhE/m^2) and simultaneously to improve the energy efficiency rating of the case building by adding a mix of different measures mentioned in Table 12 but it would require a lot of investments and paypack periods might be unreasonable. In addition, the case building seems to be more energy efficient in compared with the typical old office building that complicate to find cost-effective alternatives to improve the energy performance.

5.4.4 Energy Performance of Tenant

One tenant of the case building was simulated to investigate if their goals mentioned in their energy efficiency plan (2012) are achieved. The rented area is 2489 m^2 and the premises of the tenant are mainly situated on the fifth floor. The tenant has 117 people working in their spaces and the spaces are mainly offices. Senate Properties has a goal to decrease the heating and electric consumption of its properties 6 % by the year 2016. In the energy efficiency plan (2012) of the case tenant, goals were set for reducing energy consumption and improving energy efficiency. The used start level is the year 2010. The goals of the tenant were related to the electricity consumption. They aimed at reducing

1. the electricity consumption 30 % by 2016 and 50 % by 2020;
2. the electricity consumption per a worker 30 % by 2016 and 50 % by 2020; and
3. the electricity consumption per a rented area 30 % by 2016 and 50 % by 2020.

The measures of the energy efficiency plan (2012) related to energy efficient use are:

- In June, July and August the lights of corridors are switched off;
- the old workstations are replaced by laptops;
- lights and computer screens have to be switched off when leaving a working point and computers have to be fully switched off at the end of the day;
- copy machines and laptops go to powersave mode when they are not used; and
- in toilets, copy rooms, meeting rooms and project rooms, presence detectors control the lighting. (CIMO, 2012) .

It was investigated by energy simulation if the above-mentioned energy efficiency measures are fully implemented in the spaces of the case tenant, will the energy efficiency and energy saving goals of the tenants be fulfilled. To simulate the energy consumption of the case tenant, the spaces of other tenants were removed from the light BIM. The modified model is presented in Figure 13.

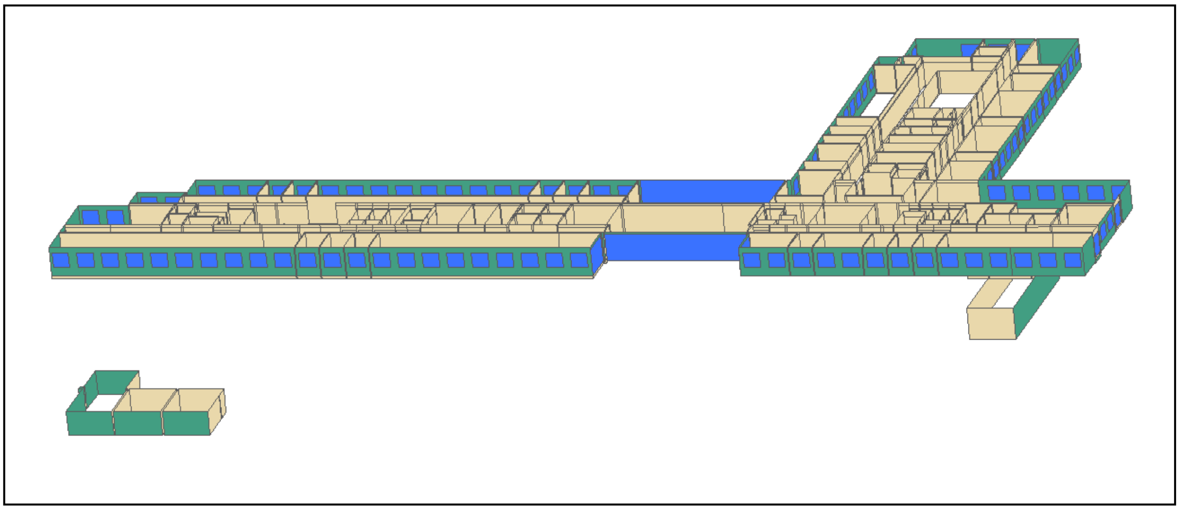


Figure 13 Light BIM of Case Tenant

Every space was defined separately according to the space type when the ventilation rates and the set points of the temperature for heating could be defined according to the requirements of the quality standard. The estimated loads from people, ventilation and devices and their operating schedules were defined to the spaces. The amounts of people in office and quiet rooms were delivered from Optimaze.net. In Figure 14, the western part of the Optimaze space model is presented.

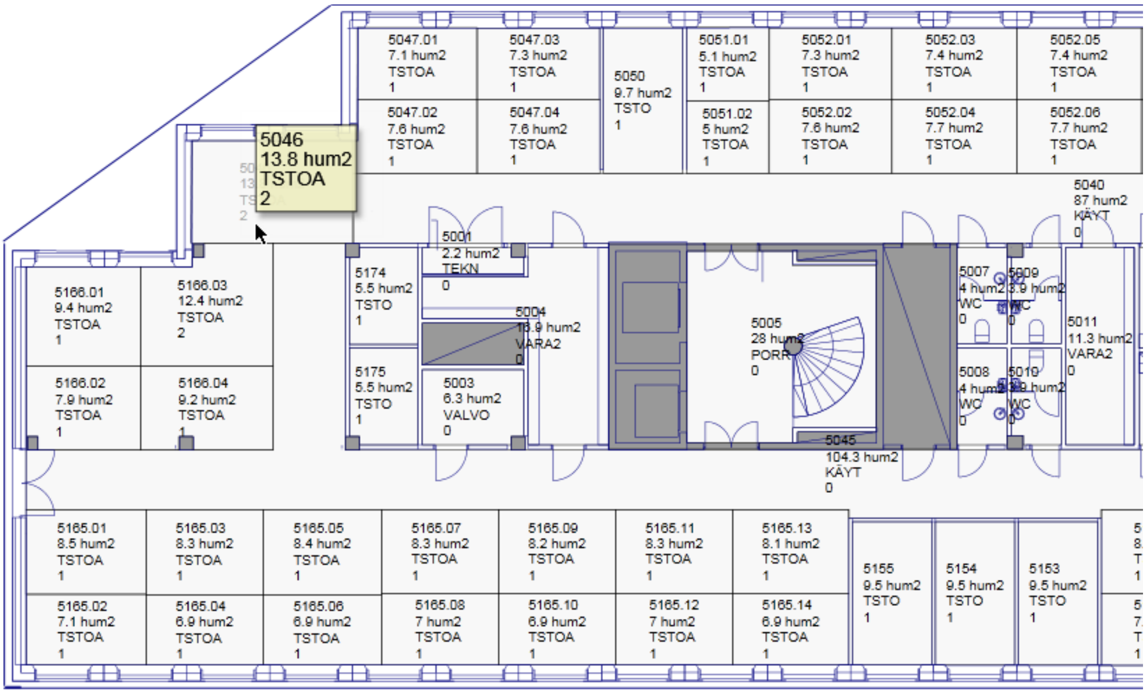


Figure 14 Optimaze space model

It was assumed that in offices there is an energy efficient laptop (10W) (EU Energy Star, 2013) and an average office light (60W) per one person. In other spaces, heat loads were estimated according to the average loads in office buildings. In Table 12, ventilation rates, internal loads and their operating schedules of different space types is presented. The initial data of the simulation in the current use (2013) was based on the assumption that previously mentioned energy efficiency measures are fully implemented.

Table 12 Ventilation Rates, Internal Loads and Their Operating Schedules

Type	qv	P_{people}	Operating schedule	$P_{lighting}$	Operating schedule	$P_{devices}$	Operating time
Office, quiet room	2,1 l/sm^2	125 W/per	mo-fri 8-17 (av 61%)	60 W/per	mo-fri 8-17 (av 61%)	10W/per	mo-fri 8-17 (av 61%)
Meeting room	4 l/sm^2	22,5 W/m^2	mo-fri 9-11, 13-16 (50%)	20 W/m^2	mo-fri 9-11, 13-16 (50%)	5 W/m^2	mo-fri 9-11, 13-16 (50%)
Corridor	1 l/sm^2	1,5 W/m^2	mo-fri 8-17 (50%)	10W/m^2	mo-fri 8-17 (50%), in summer off		
Toilet	4 l/sm^2			10W/m^2	mo-fri 7-19 (av 20%)		
Kitchenette	10 l/sm^2	3,8 W/m^2	mo-fri 8-17 (50%)	10 W/m^2	mo-fri 6-18 (100%) 18-19 (50%)	70W/m^2	mo-fri 8-17 (50%)
Copy room	2 l/sm^2			10 W/m^2	mo-fri 8-17 (av 61%)	100 W/m^2	mo-fri 8-17 (av 61%) + night use 20%
IT space	1,5 l/sm^2					100 W/m^2	mo-su 24 h (50%)

The realised energy consumption in 2010 and the simulated energy consumption in 2013 are presented in Table 13. The realised energy consumption (2010) is presented relative to the rented area because there is not separately consumption measuring.

Table 13 Realised Energy Consumption (2010) and Simulated Energy Consumption (2013)

Energy consumption	Unit	Realised (2010)	Simulated (2013)	Difference %
Heating energy	MWh	221	223	0,9
	MWh/per	2	2	0
	kWh/m^2	89	90	0,9
Electric energy	MWh	229	95	-58,5
	MWh/per	2	1	-50
	kWh/m^2	92	38	-58,5
Total	MWh	450	318	-29,3
CO2 emissions	1000 kg CO2	89	76	-15,2
Cooling energy	MWh	-	24	
	MWh/per	-	0,2	
	kWh/m^2	-	10	

In addition to heating and electric energy consumptions, the simulation gives the cooling energy consumption of the tenant but this information cannot be compared because the cooling energy consumption is not mentioned in the energy efficiency plan. The simulated heating energy consumption in 2013 was 0.9 % higher than the realised heating energy consumption in 2010. The reason for this is probably the improved control of lighting and the new more energy efficient office devices in 2013. The smaller heating loads of the new devices and the control of lighting increase the heating demand. However, the realised heating consumption in the energy efficiency plan is still just approximate because it is not based on the real measuring but calculated relative to the rented area.

The simulated electric energy consumption in 2013 was 59 % smaller than the realised electric energy consumption in 2010. Judging from this result, the goal 1 is achieved if the behaviour and control stays as it was entered in the energy efficient plan of the tenant. The electricity consumption per tenant is decreased 50 % and the electricity consumption per rented area is decreased 59 % in the current use. Moreover the C02 emissions were 15 % smaller in the simulated case 2013 than in 2010. In conclusion, all the energy saving and energy efficiency goals are achieved and even exceeded when the energy efficiency measures are fully implemented.

5.4.5 Key Findings

The key findings of the energy calculations based on a light BIM were:

▪ A light BIM can be created by two methods; either modelled based on an existing building's architectural drawing or created from an existing 2D space model of a building, in which case the modelling work is reduced.

▪ Energy calculations proved that a light BIM can be used in:

- Calculating E-value and creating EPC for an existing building;
- Investigating energy performance measures for an existing building that answer the energy performance requirements of renovations in the decree (2013/4);
- Calculating the energy consumption of one tenant and the energy consumption distribution between different tenants;
- Investigating the influence of behavioural change to a tenant's energy consumption; and
- Setting energy efficiency goals for a tenant.

7 QUESTIONNAIRE STUDY

This chapter consists of a questionnaire study which was realised as an online survey. The aim of the online survey was to obtain the wider view on the demand of the office tenants for energy efficiency services. At first, research methods and material are described. Then the progress of the questionnaire study is presented. In conclusion the results are demonstrated mainly using quantitative methods but including also some qualitatively analysis.

7.1 Research Methods and Material

The aim of questionnaire study is to produce a valid and the most possible correct data. The realisation of the questionnaire study is not unproblematic due to various X-factors influence on the study. The sources of error are mainly related to the reliability of the metering, the right choices between methods and the successful sample. (Taanila, 2012).

The questionnaire study is mostly quantitative study. In the quantitative study, statistical methods are applied. The survey data often consists of measured numbers. Even if the questions are presented verbally, the responses are expressed numerically. The additional information and responses are presented verbally if the numerical presentation is difficult. The verbal responses are mainly analysed qualitatively but the given results can be compacted and present in quantitatively. The most important is to select the appropriate approaches for each situation. (Vehkalahti, 2008, pp. 12-13).

The questionnaire study was realised as an online survey during August and September 2013. The survey questions are presented in Appendix 3. The aim of the survey was to investigate the demand of office tenants for energy efficiency services enabled by BIM. Mainly fixed choice questions were used to simplify and expedite answering. The choices in the survey were based on the answers of the interviewed tenants. In a minor part of the questions, respondents had an opportunity to respond verbally or add a reason for their answer. The responses were analysed primarily by quantitative methods but also qualitative analyse was utilised depending on the type of a question.

7.2 Progress of Study

The general view of the population is based on a sample whereas the sample must present characteristics of the population (Taanila, 2012). The population of this study are office tenants in Finland. To achieve a reliable result of the study, the online survey was sent only on people who are responsible for the leases or otherwise in the position of a decision-maker in organizations. It was assumed that these people would have enough knowledge of responding to questions about the energy issues and the leases of organisations.

The respondents were attempted be reached over a month mainly contacting direct to the owners of office properties in order to reach a large number of tenants at the same time. The research progress was challenging due to the fact that the most of the owners did not allow disturbing their tenants with the survey. Finally, the online survey was sent to 150 people mainly operating in the properties owned by insurance companies and the customers of Rapal.

The aim was to obtain a sample of 30-40 respondents in which case the response rate would be 20-30 % that is a successful response rate for an online survey. (SurveyMonkey, 2013). Even if the reminders were sent, only a total of 25 people responded to the survey. The response rate was 16 % that is little below the aim and therefore decreases the generalisation of the study but is still satisfactory when taking into account the nature of this study.

7.3 Results

7.3.1 Basic Information of Respondents

In total 25 representatives of different office tenants responded to the online survey. The organisations of the respondents were different sized and operated in different fields all over Finland, which enabled an interesting and diversified research data (Figures 16, 17). 56 % of the respondents were responsible for the leases of their organisation.

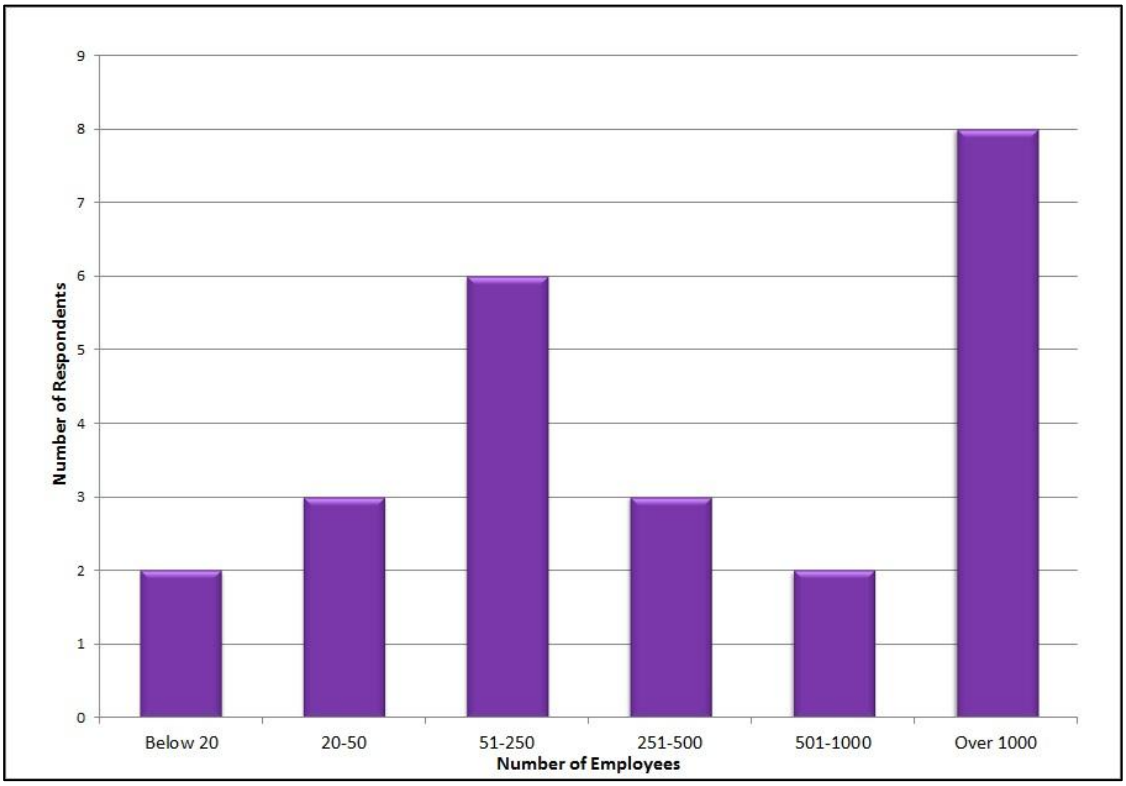


Figure 15 Distribution of Number of Employees (n=24)

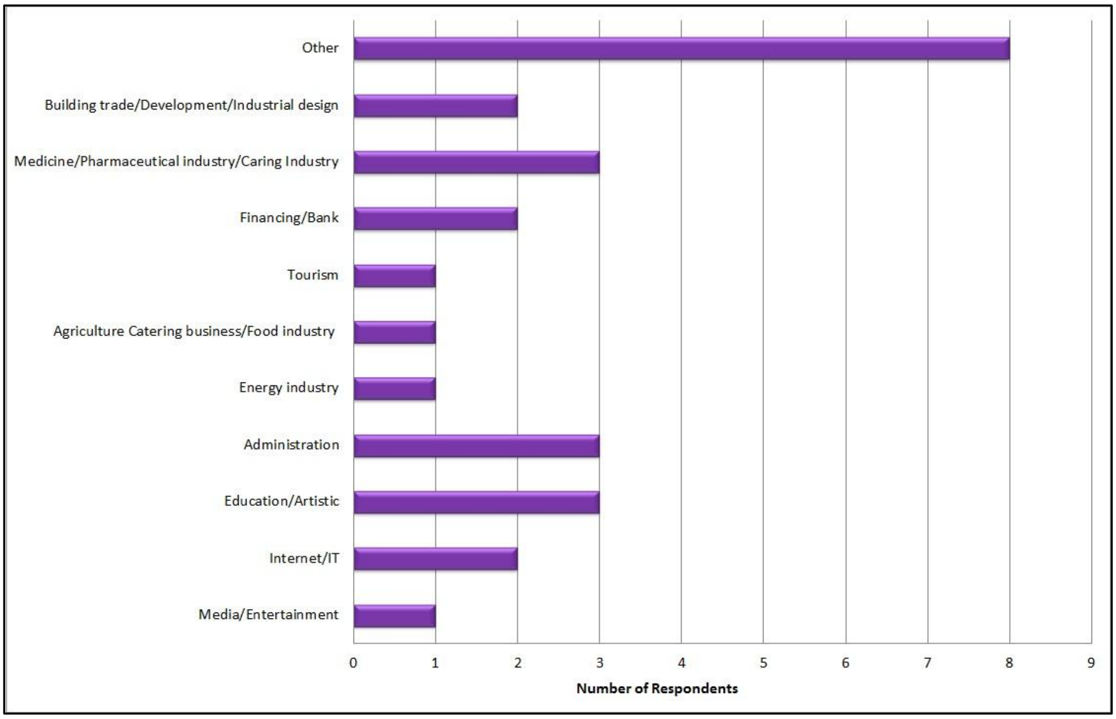


Figure 16 Distribution of Fields of Business (n=25)

7.3.2 Energy Efficiency Targets and Realised Measures

Almost 90 % of the office tenants had targets related to sustainable development and energy saving (Figure 17). In addition, 50 % of the tenants had made an energy efficiency agreement. Some of these respondents may be in the public sector because they are under an obligation to improve their energy efficiency (Motiva, 2011).

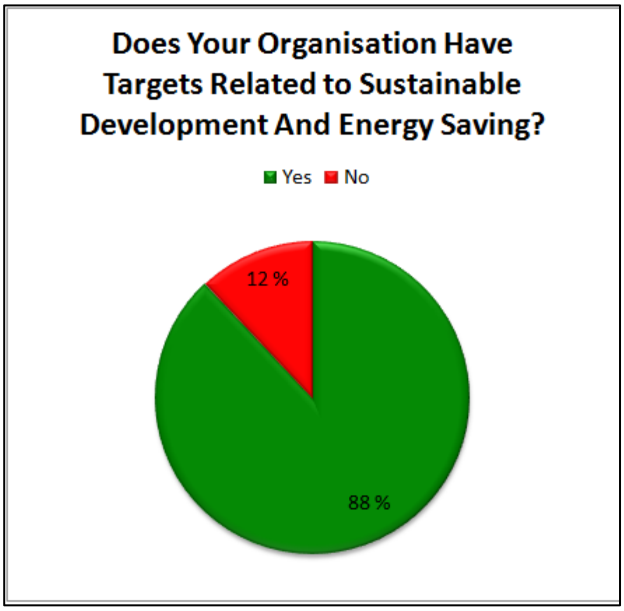


Figure 17. Does Your Organisation Have Targets Related to Sustainable Development And Energy Saving?

The targets of the tenants distributed rather evenly between different areas (Figure 18).

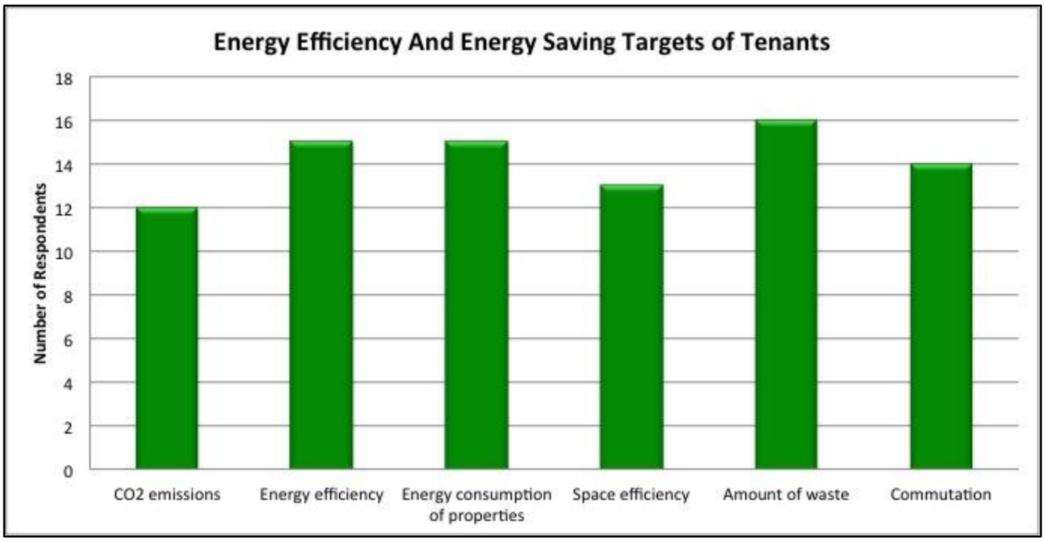


Figure 18 What Issues Are Your Targets Related To? (n=22)

Only two of the office tenants did not have any energy efficiency measures implemented in their property. Almost 70 % of the tenants had informed users and used consumption monitoring and reporting in order to improve the energy performance of the property (Figure 19).

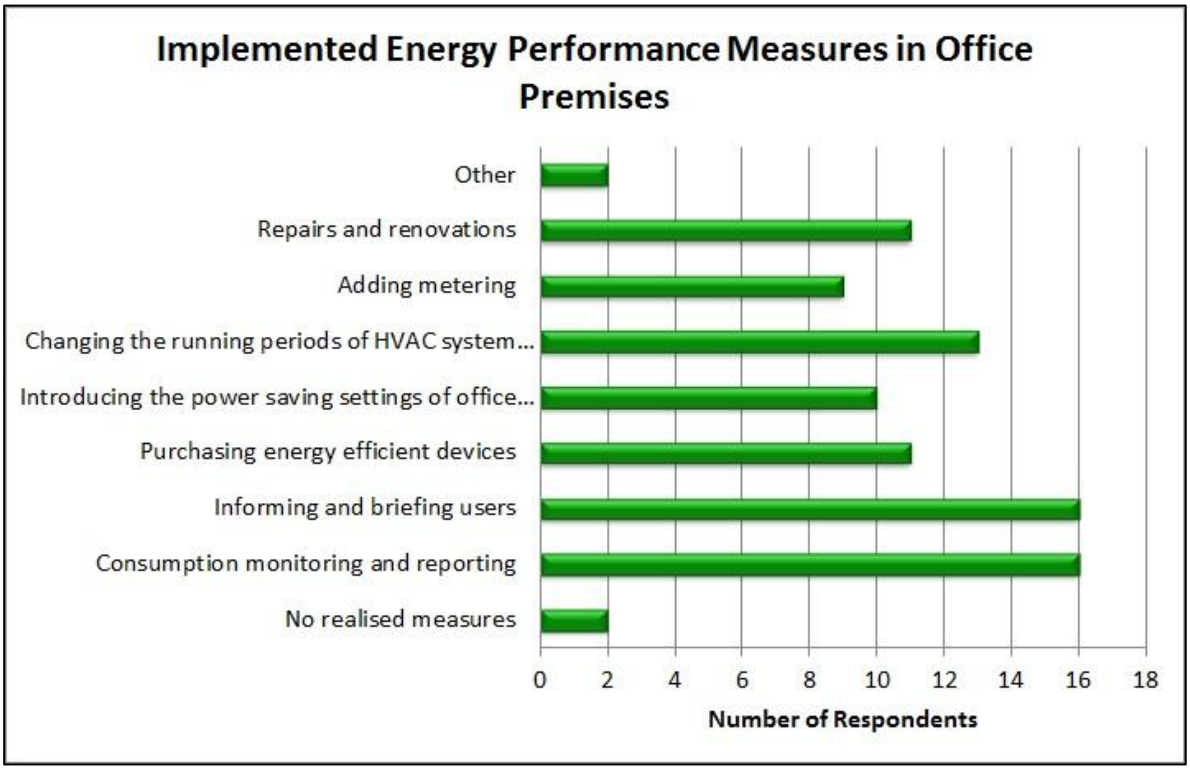


Figure 19 What Measures Have Been Implemented To Improve Energy Performance of Your Property? (n=23)

70 % of the tenants have had discussions about energy efficiency and saving issues with their lessor. Almost half of the office tenants have been discussed about consumption metering with their lessor and 30 % of the tenants have had meetings related to energy efficiency. (Figure 20).

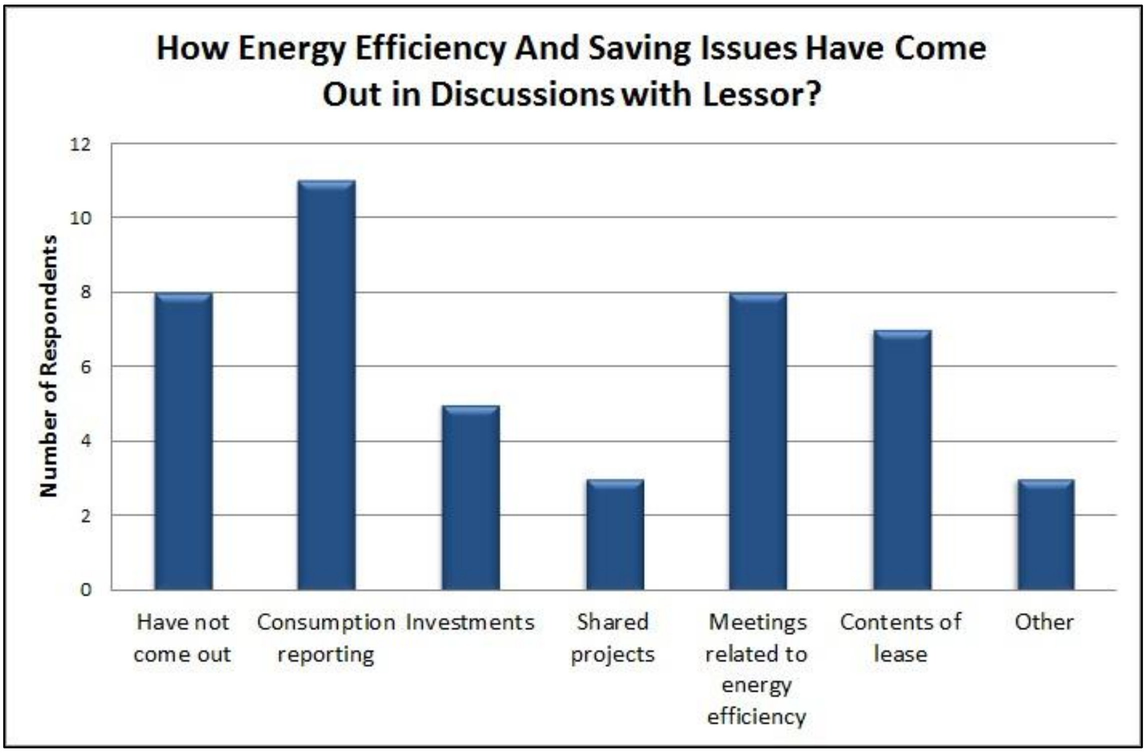


Figure 20 How Energy Efficiency and Saving Issues Have Come Out in Discussions With your lessor? (n=24)

The Green Office was not remarkably common among the office tenants; 16% of the tenants were a part of the Green Office and only 14% were planning to join it (Figure 21, 22).

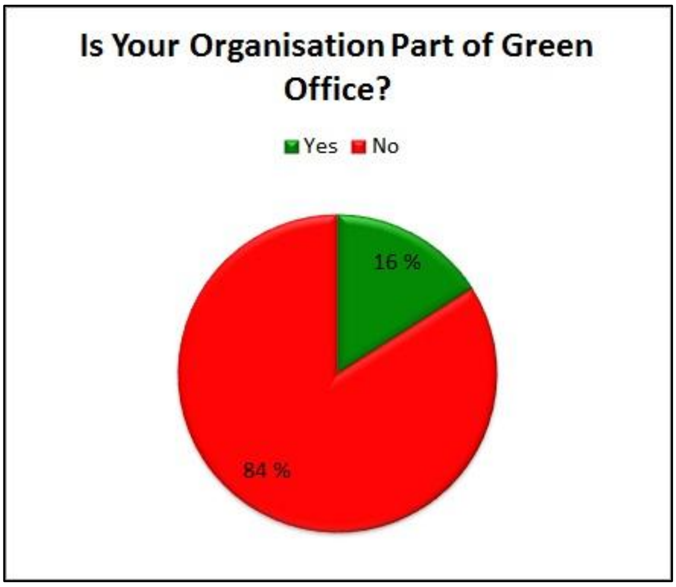


Figure 21 Is Your Organisation Part of Green Office? (n=25)

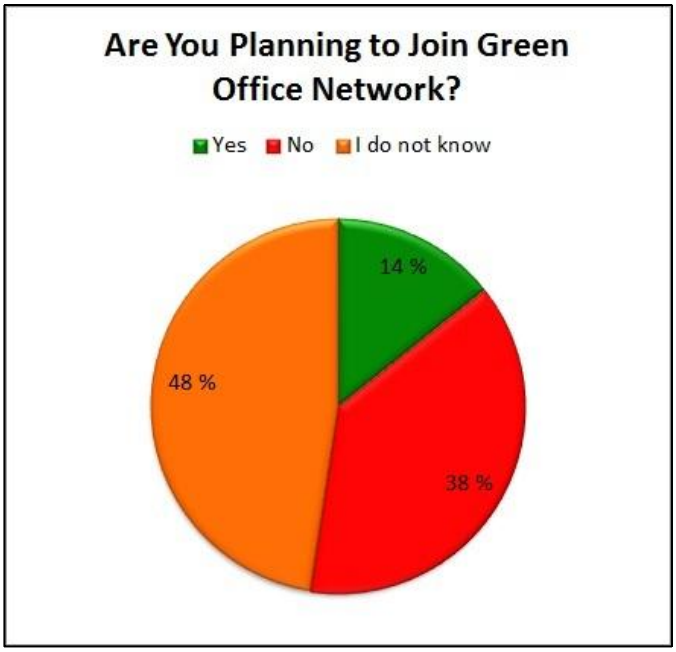


Figure 22 Are You Planning to Join Green Office Network? (n=21)

The knowledge of the tenants of the environmental assessment classification of their property was poor. Over half of the respondents did not know whether their property had one and 44 % responded that they do not have it (Figure 23).

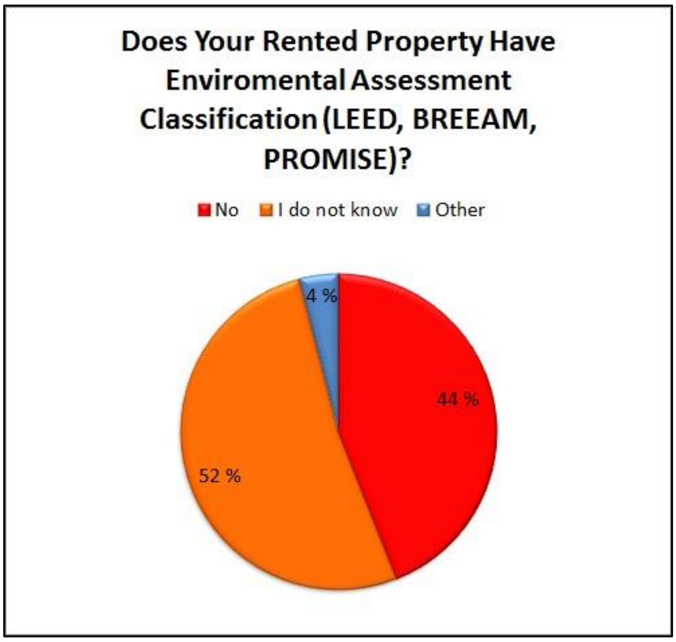


Figure 23 Does Your Rented Property Have Environmental Assessment Classification (LEED, BREEAM, PROMISE)? (n=25)

7.3.3 Views on Energy Performance Certificates

EPC was familiar over 80 % of the office tenants (Figure 24).

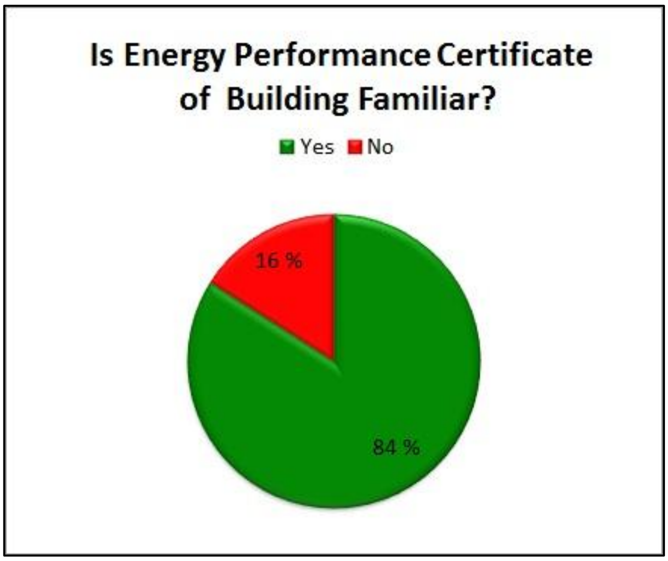


Figure 24 Is Energy Performance Certificate of Building Familiar? (n=25)

EPC was considered important when tenants are searching for new office premises. Over 40 % of the tenants considered it important and over 20 % really important. The reasons for its importance were the lower maintenance costs and the lower risks of the increasing energy expenses in properties that have a high energy efficiency rating. Instead, to the current premises EPC was considered less important (Figure 25).

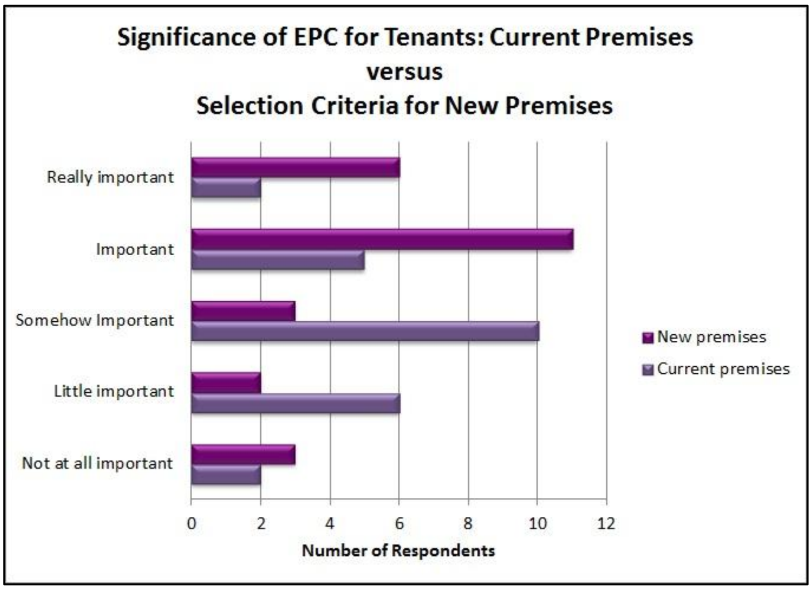


Figure 25 Significance of EPC for Tenants: Current Premises versus Selection Criteria for New Premises (n=25)

7.3.4 Interest in Green Leases

Only 12 % of the tenants were familiar to the Green Lease model (Figure 26). None of the tenants used the Green Lease model. However, almost 80 % of the tenants liked the concept that their behaviour would have an effect on the contents of their rent (Figure 27). After the basis of the Green Lease model was explained to the tenants, 75 % was interested to use it in the near future (Figure 28).

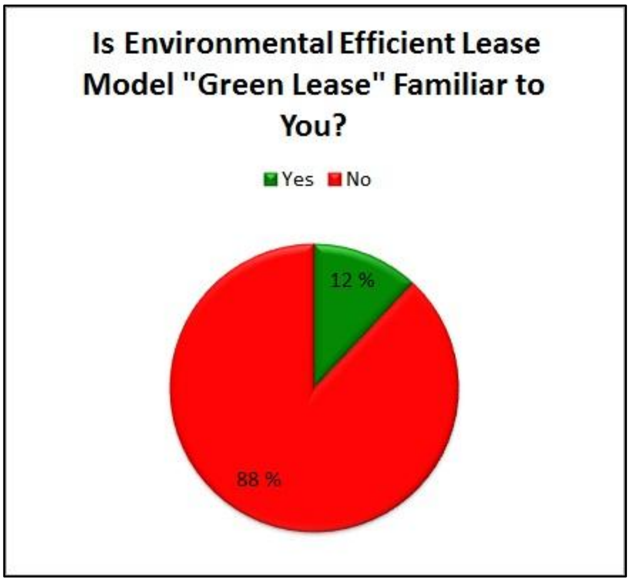


Figure 26 Is Environmental Efficient Lease Model "Green Lease" Familiar to You? (n=25)

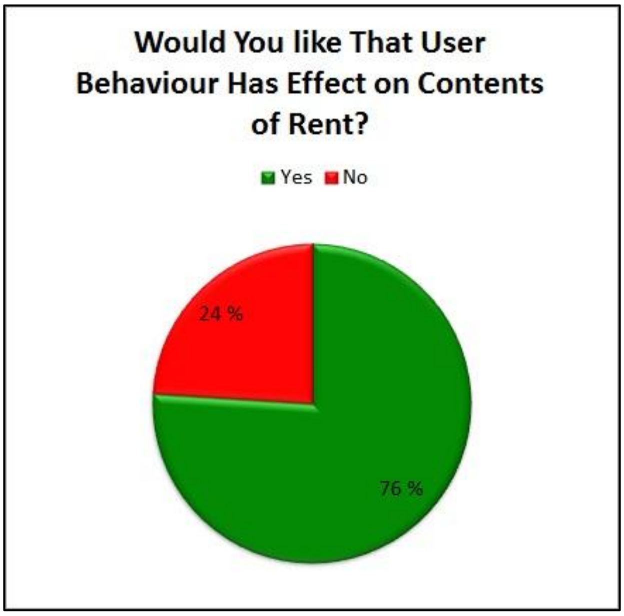


Figure 27 Would You Like That User Behaviour Has Effect on Contents of Rent? (n=25)

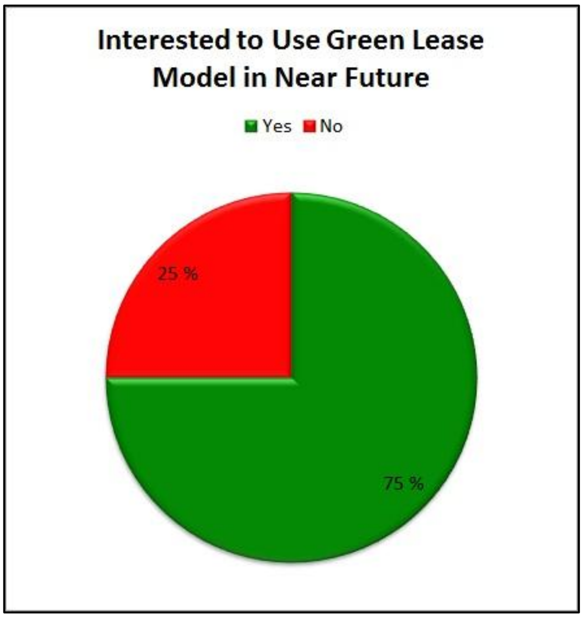


Figure 28 Could Your Organisation Be Interested to Adopt Green Lease Model in Near Future? (n=24)

The tenants were asked to select from the different risks of the Green Lease model. 20 % of the office tenants did not notice any risks in the Green Lease models. 70 % of those who responded considered as a risk the availability and reliability of the energy consumption information of premises and 50 % of the respondents considered the Green Lease model to increase bureaucracy and work (Figure 29).

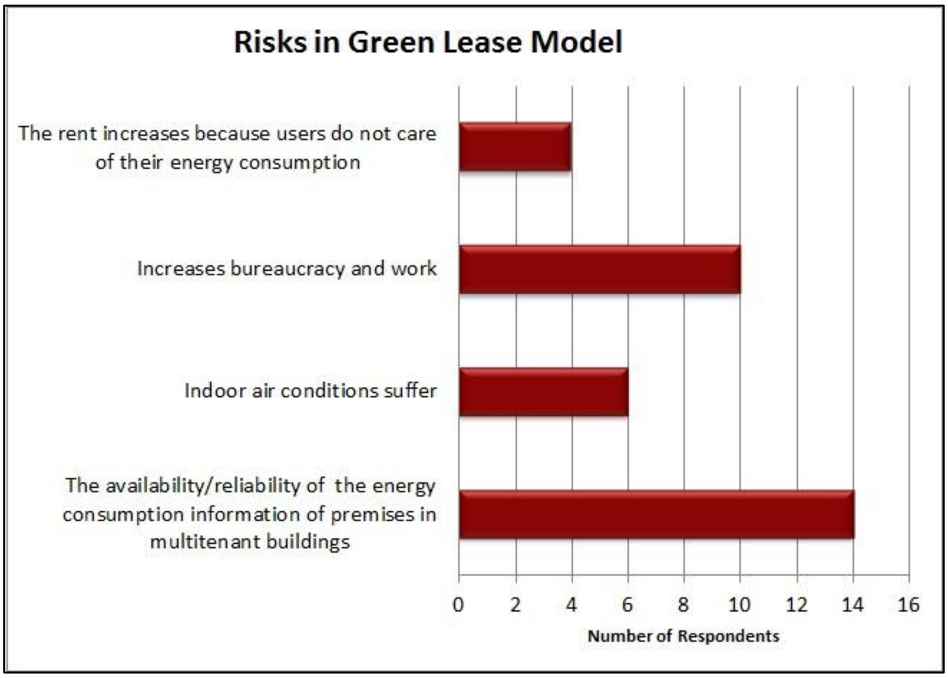


Figure 29 Which of Next Risk Has Green Lease Model? (n=20)

7.3.5 Conditions in Office Premises

Two thirds of the office tenants were satisfied with the current conditions of their office premises (Figure 30). For those who were unsatisfied, the most common problem was the variation of the temperature (Figure 31).

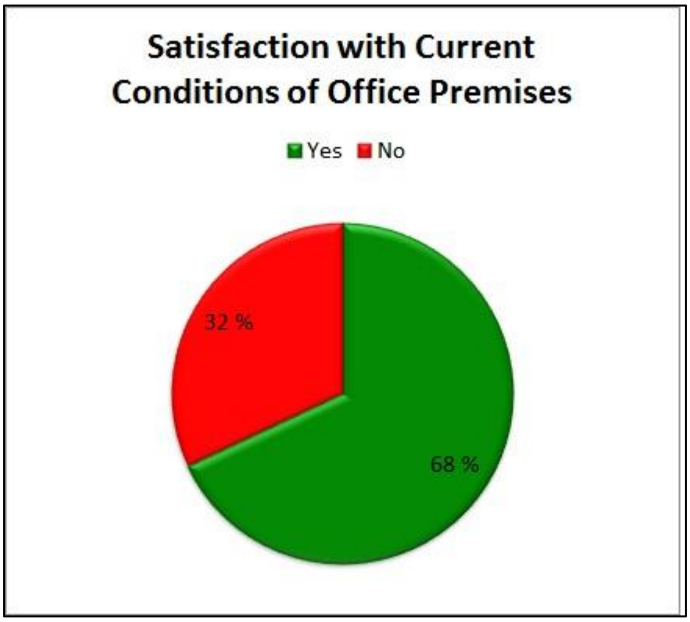


Figure 30. Are You Satisfied With Current Conditions of Your Office Premises? (n=25)

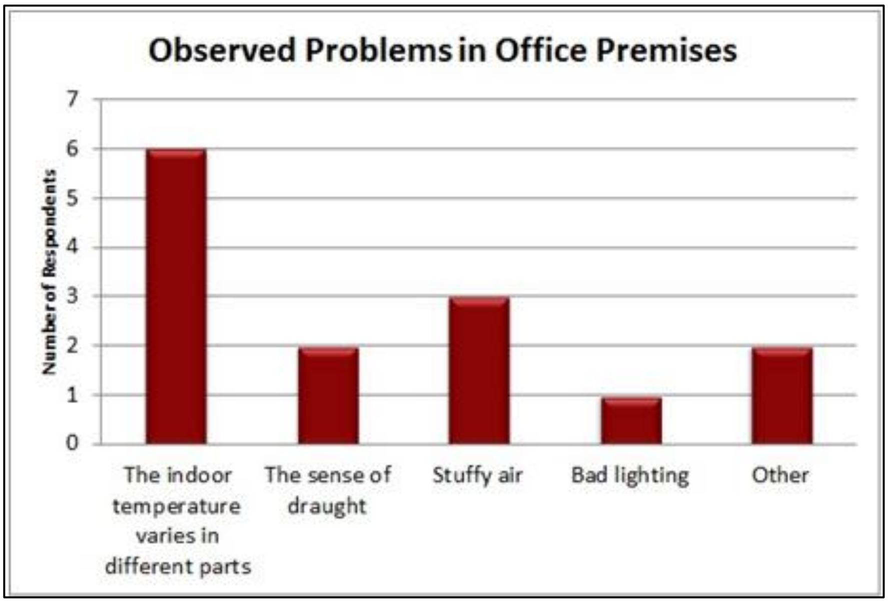


Figure 31 What Kind of Problems Have You Observed? (n=6)

The opinions of the office tenants about a building automation system divided in two parts (Figure 32). 56 % of the respondents preferred the building automation system to the control of users due to the fact that the reaction of building automation was considered more rapid and accurate than the user's control.

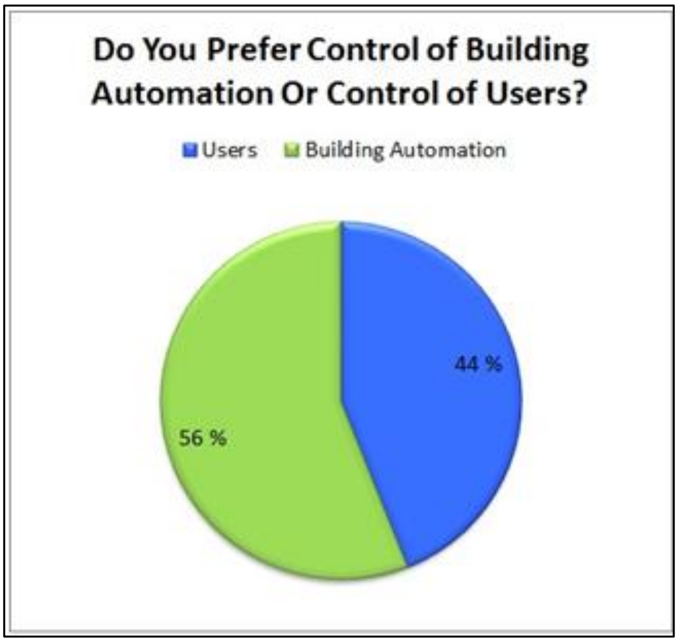


Figure 32 Do You Prefer Control of Building Automation Or Control of Users? (n=25)

7.3.6 Consumption Metering and Reporting

The studied consumption areas in the survey were electricity, heating, cooling, water and C02 emissions. The questions related to metering and reporting seemed to be difficult for the respondents. They were fairly aware of the current metering systems but were not familiar with consumption reports. The unawareness of some respondents made difficult to obtain a reliable general view of consumption metering and reporting in the offices.

Electricity

Nearly 60 % of the office tenants had the separate metering for electricity consumption. Half of the office tenants were given the reports of electricity consumption once a month and 30 % did not have knowledge of reports. The reports were mainly based on the separate metering. The electricity consumption was the only one of which some tenants had real time reporting (Figures 33-34).

Heating and Water

The responses of heating and water consumptions were similar. A little less than 20 % of the office tenants had a separate metering for heating or water consumption. Nearly 70 % of the respondents had only one heating or water metering for the whole property. Nearly 40 % were given the monthly reports of heating consumption but other 40 % did not have knowledge of reports. About 30 % were given the monthly reports of water consumption but other 40 % did not have knowledge of reports (Figures 33-34).

Cooling

Below 10 % of the office tenants had the separate metering for cooling consumption. A little less than 60% of the office tenants had one cooling metering for the whole property. 20 % of the tenants did not have knowledge of cooling metering and 60 % were not aware of cooling reports (Figures 33-34).

CO_2 emissions

About 20 % of the office tenants were given the yearly reports of CO_2 emissions. Almost half of the office tenants did not have knowledge of their CO_2 emissions (Figure 34).

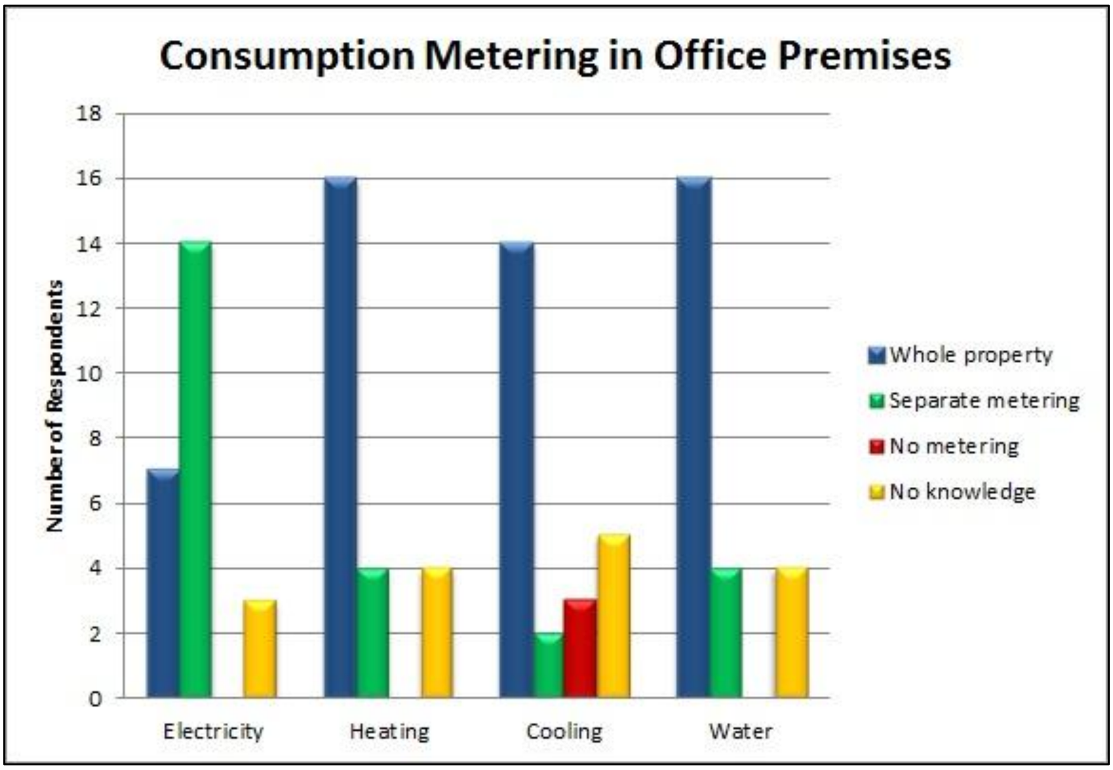


Figure 33 How is Energy Consumption Measured? (n=24)

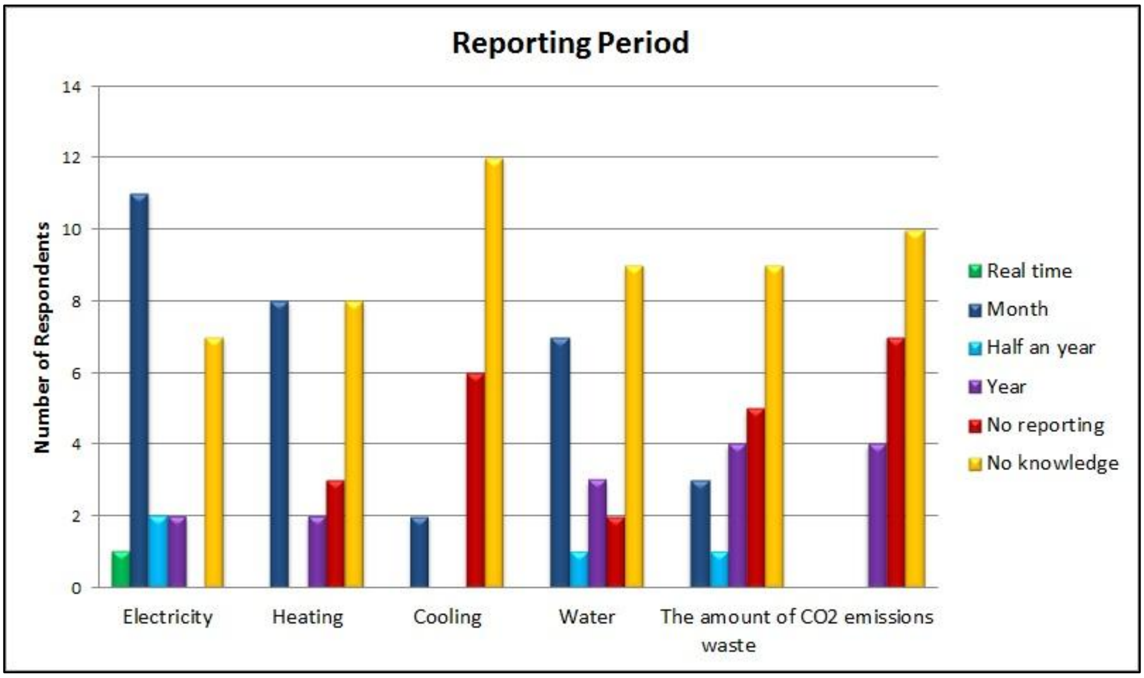


Figure 34 How Often Is Energy Consumption Reported? (n=23)

The office tenants were enquired for the interesting quantities of reporting. Indoor air quality was the most interesting quantity among the office tenants. Moreover, 70% of the tenants were interested to know the differences of energy consumptions compared with similar organisations and the effect of behaviour on energy consumption (Figure 35).

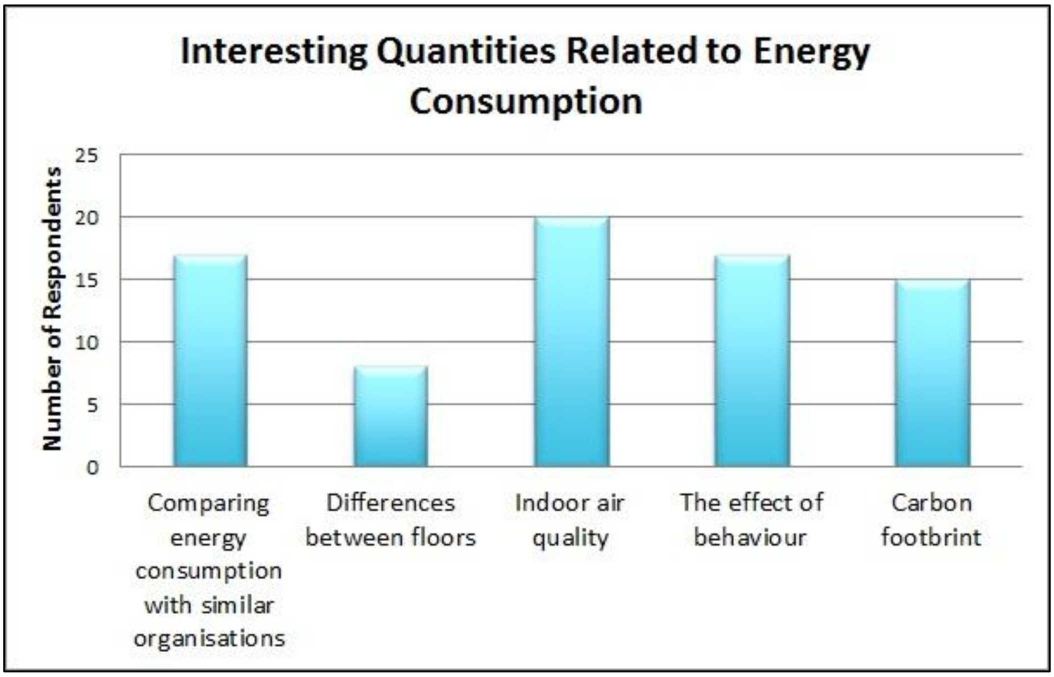


Figure 35. Which of Next Quantities Are You Interested in? (n=25)

Almost 40 % of the office tenants considered, the traditional indicator kWh/m2 and 30 % of the tenants considered the indicator €/m^2, be the best to describe the energy efficiency of a property (Figure 36).

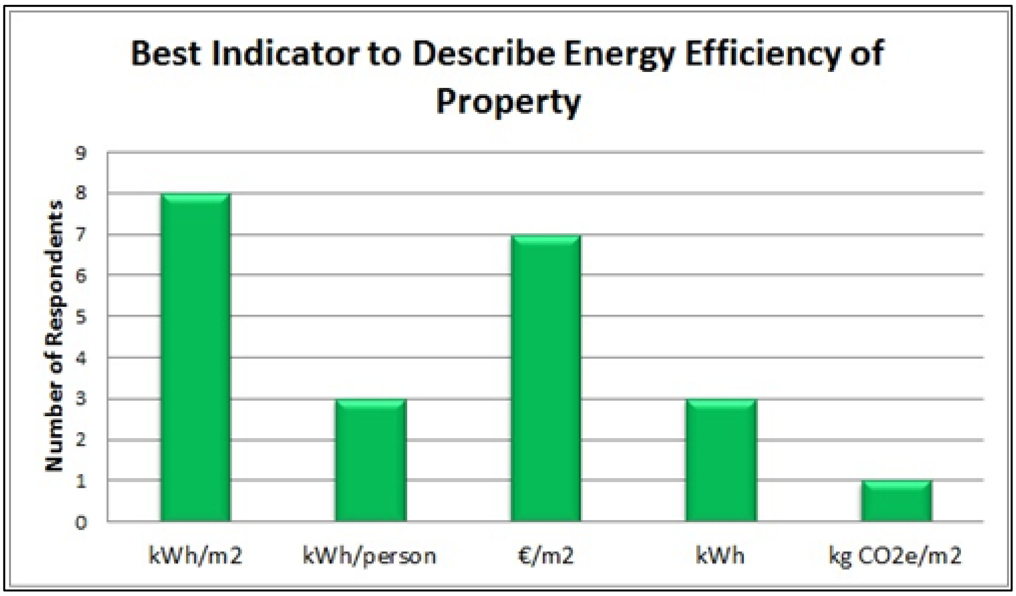


Figure 36. Which of Next Indicators Describes Energy Efficiency of Property at Best? (n=22)

7.3.7 Key Findings

Key findings of the questionnaire study were:

▪ Most of the office tenants had targets related to sustainable development and energy saving. The most common implemented energy performance measures in office premises were informings users of energy efficient behaviour and consumption measuring and reporting. However, mainly the electricity consumption had the separate measuring in office premises. The traditional kwh/m2 was found to be the best indicator to describe the energy consumption of a premise.

▪ The office tenants were interested in:

- EPC and the given energy performance rating of a property when searching for new premises
- Adopting Green Lease Model and the idea that behaviour would have an effect on the rent
- Differences in energy consumptions compared with similar organisations
- The effect of behavioural change on energy consumption

- The indoor air quality in office premises

8 CONCLUSIONS

8.1 Analysis of Results

The objective of this research was to investigate which services light BIM (enables for improving the energy performance of existing office buildings. The objective was answered by a literature review and an empirical study which consisted of a case study and a questionnaire study. The case study consisted of the interviews of tenants and energy simulations that were based the light BIM of the case building. The literary review introduced the theory and regulations behind the energy performance of office buildings and different measures to improve it. In addition, it was answered to the question how BIM can be utilised in the energy performance analysis of a building. The empirical study proved that a light BIM enables for various different services for improving the energy performance of existing office buildings.

According to the literary review, the energy performance of a building consists of various factors. Usually, the energy performance is defined as a comparable, standardised use based on energy consumption. New Finnish EPCs are based on the calculated energy consumption in standard use (E-value) and therefore they increase the need for dynamic energy simulation. Investigating the initial values of E-value calculation can be difficult and time consuming but existing BIM models can be utilised and decrease the workload.

The end-users have a significant effect on energy efficiency because they are responsible for the use, particularly for office equipment and lighting. Incentives such as environmentally efficient Green Lease models play an important role in improving energy efficiency. Green Leases have not come in the general use because of their often complex contents and the difficult verifying energy consumptions between different tenants in multitenant buildings.

The results of the interview study and the questionnaire study supported each other. Most of the office tenants had energy efficiency targets and end-users were informed of energy efficient behaviour. The most significant methods, in order to encourage end-users in energy saving actions, were giving feedback on their behaviour and practical advice how to change it. The tenants were interested in the effect of behavioural change on energy consumption, comparing their energy consumption with similar organisations and the indoor air quality in their premises. EPC and the given energy performance rating of a property was found to be the most significant in long leases and particularly when searching for new office premises.

Most of the office tenants were interested to use the Green Lease model in the near future. According to the interviewed tenants, Green Lease should be easily realised and based on the measured consumption. However, the separate consumption metering was rare in office premises according to the survey. The separate metering of electricity consumption was the most common in comparison with other asked consumptions (heating, water, cooling).

In this study, a light BIM refers to a BIM that only consists of required information in adequate accuracy to investigate the energy performance of a building. A light BIM of an existing building can be created by two methods. It is either modelled based on a building's architectural drawing or it is created from an existing 2D space model. In the latter case, the modelling work is reduced. Energy simulations demonstrated that a light BIM can be utilised to simulate and prove the effect of behavioural change to energy consumption and to set the viable goals for the energy consumptions of different tenants, for example in energy efficiency plans. Moreover, the distribution of energy consumptions between different tenants can be investigated if the information of the current use is available. However regular consumption monitoring is required to guarantee that the given energy performance goals have been fulfilled after implemented measures. This requires investments in existing buildings.

In addition, the energy simulations demonstrated that the light BIM can be utilised in creating Energy Performance Certificates including E-value calculation and giving proposals for energy performance measures. In the case building, the most efficient E-value improvements were proved to be decreasing the lighting power and improving the efficiency of the heat recovery. Adding solar heating or solar electricity to the building were proved to be efficient measures as well.

The energy calculations of the study demonstrated that a light BIM can be utilised at least in two of the four important elements of Green Lease. Those elements were: the behavioural effect of a tenant (1) and the effect of different energy forms to energy consumption (2). By simulating a light BIM, both the effect of behavioural change and the change of energy form on energy consumption can be investigated.

A third element of Green Lease, indoor air quality, was the most interesting quantity among the respondents of the survey. The indoor air quality of office premises is possible to investigate based on a light BIM. However, indoor air quality calculations were not covered in this study in order to stay within the limits of the thesis. With a help of the light BIM, the influence of both contracting parties on the energy consumption can be recognised and the base of Green Lease can be created. However, when the Green Lease model is in use, consumption monitoring is still required to evaluate the real cost distribution between the owner and tenant.

In conclusion, this study proved that a light BIM enables various services to improve the energy performance of existing office buildings. The light BIM can be utilised in:

▪ Creating Energy Performance Certificates and a base of Green Lease models;
▪ Investigating the energy performance measures of office premises;
▪ Investigating the distribution of energy consumptions in multitenant buildings;
▪ Investigating the effect of the behavioural change of users;
▪ Setting energy efficiency targets for tenants; and
▪ Investigating the indoor air quality of buildings.

8.2 Reliability of Results

The literature of the literary review of the study can be considered as reliable and sufficiently wide. The literature consisted of international and Finnish literature and publications such as scientific articles, Finnish building regulations and research reports. In addition, web pages were used to find updated information and the opinions of experts.

The interview questions proceeded in the same order with all the respondents. All the interviews were recorded. The results of the interviews were transcribed as soon as possible after an interview so that the results would be in the fresh memory and the reliability of the results would stay adequate. To obtain a wider angle of view to the different energy efficiency services, also owners and building maintenance stuff could have been interviewed.

The online survey was sent mainly to people who are responsible for the leases of their organisations or otherwise in the management group of organisations. However, some of the respondents were not so aware of or interested in the asked issues. This resulted in blank responses in some of the questions. The response rate of the survey was only 16 %, which makes the generalisation of the results difficult. Some of the people who are not so interested in energy efficiency issues may not have responded, which can have on effect on the results. However, the results of the survey can be considered at least suggestive because they were not contradicted to the results of the interviews.

In this study, the available light BIM of the case building reduced the work substantially. To estimate the real amount of the work of creating a light BIM requires more research about the information exchange opportunities between a space management application and an energy simulation application. In particular, it should be considered how the initial data of the space model is easily transferred to the energy simulation application and how many initial values still have to be determined and input manually to realise energy calculation. Further study should be carried out to compare the energy calculation results of a case where some of the initial values of the model are estimated values to a case where the exact values are used. Moreover, there should be research about how existing BIM models made for different purposes can be utilised better and in a wider variety of uses.

REFERENCES

Building Information Group, 2013. *Tietomallintamisen (BIM) käyttöönotto Suomessa - kyselyn tulokset. (The implementation of BIM in Finland - the results of the survey).* [Online]
Available at: http://rakennustieto.materiaalipankki.fi/fi/material/search
[Accessed 23 August 2013].

Ahonen, M., 2001. *Kulutusseurantaohjelmistot ja -palvelut. (Consumption metering applications and services),* Helsinki: Motiva Oy. ISBN 952-5304-13-2.

BREEAM, 2013. *BREEAM In-Use.* [Online]
Available at: http://www.breeam.org/page.jsp?id=373
[Accessed 5 May 2013].

BuildingSMART, 2013. *Industry Foundation Classes (IFC) data model.* [Online]
Available at: http://www.buildingsmart.org/standards/ifc
[Accessed 14 May 2013].

CIMO, 2012. *Energiatehokkuussuunnitelma. (Energy efficiency plan).* [Online]
Available at:
http://www.cimo.fi/instancedata/prime_product_julkaisu/cimo/embeds/cimowwwstructure/27275_Energiatehokkuussuunnitelma_CIMO.pdf
[Accessed 5 August 2013].

Darby, S., 2006. *The effectiveness of feedback on energy consumption - A review for Defra of the literature on,* s.l.: Environmental Change Institute, University of Oxford.

Decree on EPC, 2013. *Asetus rakennusten energiatodistuksesta.* Helsinki: Ministry of the Environment.

Decree on Improving Energy Performance in Renovations, 2013/4. *Ympäristöministeriön asetus energiatehokkuuden parantamisesta korjaus- ja muutostöissä.* Helsinki: Ministry of Environment.

Dong, B., Lam, K., Huang, Y. & Dobbs, G., 2007. *A comparative study of the IFC and gbXML informational infrastructures for data exchange in computational desgin support environment.* [Online]
Available at: http://www.ibpsa.org/proceedings/BS2007/p363_final.pdf
[Haettu 4 5 2013].

EEA, 2013. *Achieving energy efficiency through behaviour change: what does it take?,* Copenhagen: European Environment Agency. ISBN 978-92-9213-384-9.

EPBD, 2010/31/EU. *The EU Directive on the Energy Performance of Buildings (recast).* s.l.:EYVL, Nro L13 18.6.2010.

EU Energy Star, 2013. *Energy calculator.* [Online]
Available at: http://www.eu-energystar.org/en/en_008.shtml
[Accessed 4 September 2013].

FiSIAQ, 1996. *Finnish Society of Indoor Air Quality and Climate. Ilmanvaihdon perusteet (The basics of ventilation).* [Online]
Available at: <http://www.sisailmayhdistys.fi/portal/perustietoa/ilmanvaihdon_perusteet/>
[Accessed 19 March 2013].

Gao, C., Lee, W. & Hua, C., 2009. Locating room air-conditioners at floor level for energy saving. *Energy Conversation and Management,* Issue 50, pp. 2009-2019.

GBC Finland, 2012. *Rakennusten ympäristöluokitukset. (Building environmental assessment tools).* [Online]
Available at: http://figbc.fi/kira/ymparistoluokitukset/
[Accessed 25 May 2013].

Granlund Oy, 2013. *Riuska.* [Online]
Available at: http://www.granlund.fi/en/software/riuska/
[Accessed 3 July 2013].

Granlund, 2008. *Talotekniikka ja energiateollisuus. (Building services and energy industry).* [Online]
Available at:
http://arkkitehtuuri.tkk.fi/oppituolit/ro/opintojaksot/Talotekniikka%20ja%20energia_TENTTI.pdf
[Accessed 17 May 2013].

Granlund, 2013. *Energy reviews.* [Online]
Available at: http://www.granlund.fi/en/consultancy/technical-reviews/energy-reviews/
[Accessed 6 May 2013].

GSA, 2012. *BIM Guide for Energy Performance. Version 2.0.* [Online]
Available at: http://www.gsa.gov/graphics/pbs/GSA_BIM_Guide_Series.pdf
[Accessed 2 May 2013].

Haapio, A., 2008. *Environmental assesment of buildings.* Helsinki: Helsinki University of Technology. ISBN: 9789512295036.

Haasi, T. & Sharp, T., 1999. *A Practical Guide for Commissioning Existing buildings.* [Online]
Available at: http://www.ornl.gov/~webworks/cppr/y2001/rpt/101847.pdf
[Accessed 31 May 2013].

Haji-Sapar, M. & Eang Lee, S., 2005. Establishment of energy management tools for facilities managers in the tropical region. *Facilities,* 23(9/10), pp. 416-425. DOI: 10.1108/02632770510602351.

Heljo, J. & Vilhola, J., 2012. *Energiansäästömahdollisuudet rakennuskannan korjaustoiminnassa. (Energy saving possibilities in renovation),* Tampere: Tampereen teknillinen yliopisto, Rakennustekniikan laitos. 84 s. ISBN 978-952-15-2761-6.

Helsingin Energia, 2013. *District cooling.* [Online]
Available at: http://www.helen.fi/ymparisto_eng/kaukojaahdytys.html
[Accessed 15 August 2013].

Hemmilä, K. & Saarni, R., 2001. *Ikkunaremontti. (Window Renovation).* Tampere: Rakennustieto Oy. ISBN 951-682-654-7.

Hinnells, M. ym., 2006. The greening of commercial leases. *Journal of Property Investment & Finance,* 26(6), pp. 541-551. DOI 10.1108/14635780810908389.

Holopainen, R., Hekkanen, M., Hemmilä, K. & Norvasuo, M., 2007. *Suomalaisten rakennusten energiakorjausmenetelmät ja säästöpotentiaalit. (Energy renovation technologies and saving potentials of Finnish buildings),* Espoo: VTT. ISBN 978-951-38-6908-3.

Huhta, A., 2010. *Ympäristötehokkuutta tukeva toimistorakennuksen vuokrasopimus. (Environmentally efficient lease contract for an office building). Master`s thesis.* Espoo: Aalto University. Faculty of Engineering and Architecture.

Junnila, S., 2007. The potential effect of end-users on energy conservation in office buildings. *Facilities,* 25(7/8), pp. 329-339.

Järvinen, T. & Laine, T., 2012. *COBIM. Common BIM Requirement. Series 9: Use of models in MEP analyses.* s.l.:s.n.

Kalema, T. & Pylsy, P., 2006. *Rakennusten energiatehokkuuden ja sisäilmaston arviointi (The evaluation of the energy efficiency and indoor environment of buildings).* [Online]
Available at: http://projectapps.vtt.fi/tova/ITDynamoRapFinal.pdf
[Accessed 20 May 2013].

Kaleva, H., Lahtinen, R., Sundbäck, L. & Niemi, J., 2011. *Kiinteistöjen eko- ja energiatehokkuuden mittarit ja tunnusluvut. (The eco-efficiency and energy efficiency indicators of properties),* Helsinki: KTI Kiinteistötieto Oy. ISBN: 978-952-9833-42-9.

Kallasjoki, T., 2011. *Energiatehokas valaistus. (Energy efficient lighting).* [Online]
Available at:
http://www.dfhk.fi/fileadmin/ahk_finnland/Projekte/Exportinitiative_Ef/Kallasjoki.pdf
[Accessed 15 August 2013].

Kalliomäki, P., 2011. *Ympäristöministeriön asetus rakennusten energitehokkuudesta. (The Ministry of the Environment decree on energy efficiency of buildings). Notebook.* [Online]
Available at: http://www.ymparisto.fi/download.asp?contentid=126233&lan=fi
[Accessed 18 April 2013].

Karstila, K., n.d. *Rakentamisen tuotemallintamisen sanasto. (Terminology of Building Information Modelling).* [Online]
Available at: http://virtual.vtt.fi/virtual/proj6/proit/julkiset_tulokset/proit_sanasto_v10.pdf
[Accessed 13 May 2013].

Kaukonen, J., 2012. *Yksinkertaistettu tietomalli. (Simplified BIM).* [Online]
Available at: http://www.capisso.fi/capisso/?topic=42
[Accessed 28 March 2013].

Kauppinen, J., 2013. *Ympäristöministeriön asetus energiatehokkuuden parantamisesta korjaus- ja muutostöissä. (The Decree of Ministry of Environment on improving energy efficiency in renovations). Notebook.* [Online]
Available at: http://www.ymparisto.fi/download.asp?contentid=142234
[Accessed 6 May 13].

Kemppainen, J., 2011. *Uusien rakennusten energiamääräykset 2012. Rakennusteollisuus RT ry.*. [Online]
Available at: <www.rakennusteollisuus.fi>
[Accessed 20 March 2013].

Kiiskinen, M., 2012. *Energiatodistuslausunto.* [Online]
Available at:
http://www.skolry.fi/easydata/customers/skolry/files/Lausunnot/EnergiatodistuslausuntoSKOL2012.pdf
[Accessed 30 May 2013].

Korhonen, A. et al., 2002. *Electricity saving possibilities in household and office appliances including lighting. ISBN 951-788-347-1.* Helsinki: Työtehoseura.

KTI, 2012. *Tulevaisuuden työympäristöbarometri. (The working environment barometer of future).* [Online]
Available at:
http://www.kti.fi/kti/doc/ajankohtaista/TulevaisuudenTyoymparistoBarometri_2012.pdf
[Accessed 8 May 2013].

Kuula, E., 2012. *Asuinhuoneistojen vihreät vuokrasopimukset. (Green leases for private housing). Master´s thesis.*. Espoo: Aalto-yliopiston insinööritieteiden korkeakoulun maankäyttötieteiden laitos..

Kuula, T., 2011. *Maailman energiakatsaus. (The world energy outlook).* [Online]
Available at:
http://www.fortum.com/fi/media/ajankohtaista/artikkelit/maailman_energiakatsaus_2011/pages/default.aspx
[Accessed 9 March 2013].

Laine, T., Bäckström, K. & Järvinen, T., 2012. *COBIM.Common BIM Requirements. Series 10: Energy Analysis.* [Online]
Available at:
http://files.kotisivukone.com/en.buildingsmart.kotisivukone.com/COBIM2012/cobim_10_energy_analysis_v1.pdf
[Accessed 14 May 2013].

Laine, T. & Karola, A., 2007. *Benefits of Building Information Models in Energy Analysis.*. Helsinki, REHVA World Congress: Clima 2007 WellBeing Indoors.

Langdon, D., 2012. *Getting the most out of BIM. A guide for clients.* [Online]
Available at:
http://www.davislangdon.com/upload/StaticFiles/EME%20Publications/Other%20Research%20Publications/Davis%20Langdon%20-%20BIM%20guide%20for%20clients%20-%20Apri%20l2012.pdf
[Accessed 14 May 2013].

Lappalainen, M., 2010. *Energia- ja ekologiakäsikirja: suunnittelu ja rakentaminen. (Energy and ecology handbook: design and construction).* Helsinki: Rakennustieto Oy. ISBN 978-951-682-945-9.

Law on EPC, 50/2013. *Laki rakennusten energiatodistuksesta.* Helsinki: s.n.

Law on Land Use and Construction, 958/2012. s.l.:s.n.

Lehtonen, T. ym., 2007. *Sitran raportteja 84: Rakentamisen energiatulevaisuus. (The energy future of construction)..* Helsinki: SITRA. ISBN 978-951-563-664-5.

LVI 34-10462, 2010. *Kiinteistöjen Kaukojäähdytys. (The district cooling of properties).* Helsinki: RTS.

Masoso, O. & Grobler, L., 2009. The dark side of occupants' behaviour on building energy use. *Energy and Buildings,* 42(2010), pp. 173-177.

Ministry of Employment and the Economy, 2009. *Ehdotus energiansäästön ja energiatehokkuuden toimenpiteiksi. (Proposal for measures to energy saving and energy efficiency).* [Online]
Available at:
http://www.motiva.fi/files/2714/Ehdotus_energiansaaston_ja_energiatehokkuuden_toimenpiteiksi.pdf
[Accessed 6 May 2013].

Ministry of the Environment, 2008. *The Energy Performance Certificate of Buildings and defining E-value.* [Online]
Available at: http://www.ymparisto.fi/download.asp?contentid=82324&lan=fi
[Accessed 3 May 2013].

Ministry of the Environment, 2011. *Energiatehokkuus. (Energy efficiency).*. [Online]
Available at: http://www.ymparisto.fi/default.asp?contentid=2194
[Accessed 13 March 2013].

Ministry of the Environment, 2013a. *Rakennusten energiatodistus uudistuu. (The Energy Performance Certificate of buildings is renewed).* [Online]
Available at: http://www.ymparisto.fi/download.asp?contentid=142228&lan=fi
[Accessed 2013 March 2013].

Ministry of the Environment, 2013b. *Laki rakennusten energiatodistuksesta: usein kysyttyjä kysymyksiä ja vastauksia (Law on EPC: often asked questions and answers).* [Online]
Available at: <http://www.ymparisto.fi/download.asp?contentid=142229&lan=fi>
[Accessed 20 March 2013].

Ministry of the Environment, 2013c. *Asetus energiatehokkuuden parantamisesta korjaus- ja muutostöissä: Usein kysyttyjä kysymyksiä ja vastauksia. (Decree on improving energy performance in renovations: often asked questions and answers).* [Online]
Available at: http://www.ymparisto.fi/download.asp?contentid=142235&lan=fi
[Accessed 21 March 2013].

Ministry of the Environment, 2013d. *Korjaustieto.fi - Energy efficiency in the touch with renovation.* [Online]

Available at: http://www.korjaustieto.fi/taloyhtiot/energiakorjaukset/energiatehokkuuden-parantaminen.html
[Accessed 6 May 2013].

Motiva, 2010. *Energiatehokas ilmanvaihto. (Energy efficiency ventilation).* [Online]
Available at: <http://www.motiva.fi/files/3180/Energiatehokas_ilmanvaihto.pdf>
[Accessed 2013 March 19].

Motiva, 2011. *Jenergia-lehti: Ilmanvaihdon saneerauksessa on tärkeintä lämmöntalteenoton hyötysuhde. (When renevating ventilation, the most important issue is the heat recovery efficiency).* [Online]
Available at: http://www.jenergia-lehti.fi/index2.php?id=18&articleId=3308&type=4
[Accessed 30 July 2013].

Motiva, 2011. *The Public Sector as an Energy Efficiency Innovator.* [Online]
Available at: http://www.motiva.fi/en/public_sector
[Accessed 29 2013 September].

Motiva, 2013. *Julkisen sektorin energiatehokkuussuunnitelma. (Energy efficiency plan of the public sector).* [Online]
Available at:
http://www.motiva.fi/julkinen_sektori/julkisen_sektorin_energiatehokkuussuunnitelma
[Accessed 28 June 2013].

Motiva, 2013. *Näin luet energiatodistusta. (Read EPC like this).* [Online]
Available at: http://www.ym.fi/download/noname/%7BD128054A-1643-47C2-BB1C-1D11FF19ECA4%7D/58835
[Accessed 10 September 2103].

NBCF D3, 2012. *Rakennusten energiatehokkuus. (Energy management in buildings).* Helsinki: Ministry of Environment.

NBCF D5, 2012. *Rakennuksen energiankulutuksen ja lämmitystehontarpeen laskenta. (Calculating the energy consumption and the heating demand of the building).* Helsinki: Ympäristöministeriö, Rakennetun ympäristön osasto..

Penttilä, H., 2009. *Mikä tekee suunnitteluprojektista BIM-projektin? (What makes the design project be BIM-project?).* [Online]
Available at: http://www.mittaviiva.fi/hannu/BIM_project/index_bim_basics.html#anchor1
[Accessed 12 March 2013].

Pietiläinen, J. ym., 2007. *Tova-käsikirja: Rakennuksen toimivuuden varmistaminen energiatehokkuuden ja sisäilmaston kannalta. (Guidebook for life-cycle commissioning of buildings energy efficiency and indoor climate),* Helsinki. ISBN 978-951-38-6969-4: VTT.

Railio, J., 2011. *Energiatehokkuuden käsitteet- Mistä on kysymys? (The definitions of energy efficiency- What is it about?).* [Online]
Available at:
<http://www.sisailmayhdistys.fi/files/attachments/seminaari_2011/railio_posteri_160311.pdf>
[Accessed 15 March 2013].

RAKLI, 2001. *Kiinteistöjohtamisen sanasto. (The terminology of real estate management).* [Online]
Available at: http://www.rakli.fi/attachements/2005-08-16T13-22-0345.pdf
[Accessed 8 May 2013].

RAKLI, n.d. *Vuokran määräytymistapa. (The determination of a rent).* [Online]
Available at:
http://www.rakli.fi/linkit/kehitysjaprojektit/greenlease/riskimatriisi/vuokraperuste/
[Accessed 10 May 2013].

Rapal Oy, 2013. *Products and Services.* [Online]
Available at: http://www.rapal.fi/en/products-and-services/
[Accessed 3 July 2013].

Reddy, K. P., 2011. *BIM for Building Owners and Developers.* New Jersey, USA: John Wiley&Sons. ISBN 978-0-470-90598-2.

Reinikainen, E. & Dooley, K., 2008. *Rakennusten ympäristöluokitukset. (Building environmental assessment tools).* [Online]
Available at: http://arkkitehtuuri.tkk.fi/oppituolit/ro/Ymparistoluokitukset.pdf
[Accessed 23 May 2013].

Ropo ry, 2013. *Roportti: Kestävän rakentamisen uudet tuulet. The new winds of the sustainable construction.* Espoo: Ropo.ISBN 978-952-93-1842-1 (PDF).

Roussac, A. C. & Bright, S., 2012. Improving environmental performance through innovative commercial leasing - An Australian case study. *International Journal of Law in the Built Environment,* 4(1), pp. 6-22. DOI 10.1108/17561451211211714.

Rym Oy, 2011. *New Wow.* [Online]
Available at: <http://www.rym.fi/tutkimusohjelmat/PRE/newwow/>
[Accessed 14 March 2013].

Saari, A. ym., 2010. *Kestävä energia. (Sustainable Energy).* Espoo: Aalto-yliopiston teknillinen korkeakoulu, Rakenne- ja rakennustuotantotekniikanlaitos. ISBN (PDF) 978-952-60-3495-9.

Santamouris, M. & Dascalaki, E., 2002. Passive retrotting of office buildings to improve their energy performance and indoor environment: the OFFICE project. *Building and Environment*, Osa/vuosikerta 37, pp. 575-578.

Senate Properties, 2008. *Hakaniemenranta 6 perushanke on edennyt harjannostajaisiin. (The basic project of Hakaniemenranta 6 has proceeded on the topping off ceremonies).* [Online]
Available at: http://www.senaatti.fi/document.asp?siteID=1&docID=663
[Accessed 19 June 2013].

Senate Properties, 2012. *Green lease is already reality.*. [Online]
Available at: http://yhteiskuntavastuuraportti2011.senaatti.fi/caset/vihrea-vuokrasopimus-on-jo-todellisuutta
[Accessed 28 March 2013].

Senate Properties, 2013. *Senergia.* [Online]
Available at: http://www.senergia.fi/sivu/fi/info/
[Accessed 1 July 2013].

SFS-EN ISO 13790, 2010. *Rakennusten Energiatehokkuus. (Energy efficiency of buildings).* Helsinki: RTT.

Sinisalo, J., 2012. *Tietomallipohjaisen energia-analyysin mahdollisuudet LVI-suunnittelussa. (The usage of BIM based energy analysis in HVAC design). Master's thesis.* Espoo: Aalto University, Department of Energy Technology.

Soininen, V., 2009. *Kiinteistöjen energiansäästön vaikutus asumisterveyteen. (The effect of energy saving measures to indoor environment and healts). Enete-project.* [Online]
Available at:
http://www.ece.hut.fi/enete/Kiinteistojen_energiansaaston_vaikutus_asumisterveyteen.pdf
[Accessed 7 May 2013].

Solomon, P. & Krishna, K., 2011. The coming sustainable energy transition: History, strategies, and outlook. *Energy Policy,* 39(11), pp. 7422-7431.

Sponda, 2010. *Hyviä ohjeita työpaikan energian säästämiseksi. (Good advice to save energy in the working place).* [Online]
Available at:
http://www.sponda.fi/Documents/Energians%C3%A4%C3%A4st%C3%B6opas.pdf
[Accessed 16 May 2013].

Staller, H. & Tisch, A., 2011. *New technical solutions for energy efficient buildings: Innovative cooling concepts for office buildings.* [Online]
Available at:
http://www.seedengr.com/New%20technical%20solutions%20for%20energy%20efficient%20buildings.pdf
[Accessed 13 May 2013].

SurveyMonkey, 2013. *Survey Sample Size.* [Online]
Available at: https://www.surveymonkey.com/mp/sample-size/
[Accessed 27 September 2013].

Taanila, A., 2012. *Kyselytytkimuksen luotettavuus. (The reliability of questionnaire study).* [Online]
Available at: http://tilastoapu.wordpress.com/2012/03/13/kyselytutkimuksen-luotettavuus/
[Accessed 9 September 2013].

Tekes, 2012. *Energiatehokkaat ratkaisut. (Energy efficient solutions),* Helsinki: Tekes.

Tetri, E., Halonen, L. & Härkönen, H., 1996. *Loistelamppujen sammutuksen kannattavuus. (The profitably of switching off fluorecent lamps),* Helsinki: Motiva.

UNDP, 2009. *Promoting Energy Efficiency in Buildings: Lessons learned from international experience. United Nations Development Programme.* [Online]
Available at:
http://www.thegef.org/gef/sites/thegef.org/files/publication/EEBuilding_WEB.pdf
[Accessed 26 August 2013].

University of Jyväskylä, 2013. *Menetelmäpolkuja humanisteille. (Methods for humanists).* [Online]
Available at: https://koppa.jyu.fi/avoimet/hum/menetelmapolkuja/menetelmapolku/tutkimusstrategiat/tapaustutkimus
[Accessed 6 June 2013].

USGBC, 2009. *LEED Reference Guide for Green Building Operations&Maintenace.* [Online]
Available at: http://www.gbci.org/Libraries/Credential_Exam_References/LEED-for-Operations-and-Maintenance-Reference-Guide-Introduction.sflb.ashx
[Accessed 28 5 2013].

Vehkalahti, K., 2008. *Kyselytutkimuksen mittarit ja menetelmät. (The meters and methods of questionnaire study).* Helsinki: Tammi. ISBN 978-951-26-5760-5.

Vehosmaa, T., 2008. *Increasing the efficient use of electric energy in buildings. Master's thesis.* Espoo: University of Technology. Faculty of Electronics, Communications and Automation.

Vehviläinen, I. & Pesola, A., 2010. *Rakennetun ympäristön energiankäyttö ja kasvihuonepäästöt. (The energy consumption and greenhouse gas emissions of the built environment).* [Online]
Available at: <http://era17.fi/wp-content/uploads/2010/10/sitran_selvityksia_39.pdf>

Virtanen, H., 2010. *Energiatehokkaat vuokrasopimukset. (Environmental efficient leases (Green Lease)). Bachelor's work.*. Espoo: Aalto University.

Vuolle, M., 2012. *Uudisrakentamisen rakentamismääräykset 2012. (The building regulations of new construction).* [Online]
Available at: http://www.motiva.fi/files/5575/Uudisrakentamisen_rakentamismaaraykset_2012_Mika_Vuolle.pdf
[Accessed 14 August 2013].

Vuolle, M., 2013. *Rakennusten energiatodistus ja sen E-luvun laskenta 1.6.2013 alkaen. (EPC of buildings and calculating E-value from 1.6.2013).* [Online]
Available at: http://energiatodistus.motiva.fi/energiatodistustenlaatijat/tapahtumat/et_vuolle_verkkoon_19032013.pdf
[Accessed 22 March 2013].

WWF, 2013. *What is Green Office?.* [Online]
Available at: http://wwf.fi/en/our-earth/green-office/what-is-green-office/
[Accessed 28 5 2013].

APPENDIXES

APPENDIX 1: Interviews of tenants

A. Yleistä

1. Onko virastollanne kestävään kehitykseen ja energiansäästöön liittyviä tavoitteita? Jos on, niin mitä ja mihin ne on kirjattu?
2. Miksi lähditte mukaan energiaryhmään?
3. Miten energiaryhmän perustaminen on vaikuttanut virastonne toimintatapoihin?
4. Mitkä ovat mielestänne tärkeimmät tekijät, jotka vaikuttavat toimistorakennuksen energiatehokkuuteen?
5. Minkälaisia keinoja vuokralaisella on vaikuttaa tilojen energiatehokkuuteen ja kuinka suurena pidätte niiden vaikutusta?
6. Minkälaisia toimenpiteitä kiinteistössänne on tehty energiatehokkuuden parantamiseksi, joihin vuokralaiset ovat osallistuneet?
7. Miten energiatehokkuus- ja energiansäästöasiat ovat tulleet esille keskusteluissa vuokranantajan kanssa?

B. Green Office

1. Kuuluuko virastonne Green Officeen?
2. Miten Green Office – verkostoon kuuluminen on vaikuttanut toimintaanne?

C. Olosuhteet

1. Oletteko tyytyväisiä tämän hetkisiin olosuhteisiin?
2. Jos ette, niin minkälaisia ongelmia olette havainneet?
3. Kumpi miellyttää teitä enemmän?

- Käyttäjä voi itse säätää olosuhteisiin vaikuttavia suureita kuten lämpötilaa ja valaistusta
- Automatisointi hoitaa säädöt käyttäjän puolesta

D. Energiatodistukset

1. Ovatko energiatodistukset teille tuttu käsite? Jos ovat, niin minkälainen käsite teillä on niistä?
2. Koetteko energiatodistusjärjestelmän hyödylliseksi?

3. Millä tavalla energiatodistus palvelisi paremmin vuokralaista?
4. Voisiko energialuokituksesta olla merkitystä tilojen valintaperusteelle ja kiinnostavuudelle?

E. Green lease

1. Oletteko tietoisia yrityksenne nykyisen vuokrasopimusmallin sisällöstä? Oletteko tyytyväisiä siihen?
2. Haluaisitteko että käyttäytymisenne vaikuttaisi vuokran muodostumiseen?
3. Onko ympäristötehokkuutta edistävä vuokrasopimusmalli (Green Lease) tuttu?
4. Mitä riskejä ja mahdollisuuksia Green Lease – vuokrasopimusmallissa mielestänne on?
5. Voisitteko olla kiinnostunut käyttämään Green Lease – vuokrasopimusmallia lähitulevaisuudessa?

F. Työkalut energiatehokkuuden parantamiseen

1. Kuinka tietoisia olette kiinteistönne kulutusmittaroinnista?
2. Miten hyödylliseksi koette kulutusmittaroinnin?
3. Minkälaiset kiinteistön energiankulutukseen liittyvät indikaattorit ja raportointitavat kiinnostavat (lämpötila, käyntiajat, käyttöaste)?
4. Haluaisitteko tietää miten käyttäytymisenne muutokset vaikuttavat tilojen energiankulutukseen?
5. Haluaisitteko tietää miten investoinnit vaikuttavat tilojen energiankulutukseen?
6. Minkälaiset energiatehokkuuspalvelut kiinnostaisivat ja olisivat hyödyksi?

APPENDIX 2: Energy Simulations

E-VALUE CALCULATION INPUT DATA

Created 12.7.2013 EPi

Heated net area	21 520,0	m^2
Infiltration q50	8,5	$m^3/(h \cdot m^2)$

Building envelope	A	U	U A	%
	m^2	$W/(m^2 \cdot K)$	W/K	
External walls	5 444,7	0,25	1 351,70	21,6
External roof	3 357,5	0,16	533,43	8,5
Ground floor	3 270,7	0,17	547,04	8,7
Windows	2 477,7	1,03	2 561,57	40,9
External doors	41,1	1,40	57,63	0,9
Thermal bridges			1 217,20	19,4

Windows according to azimuth	A	U	G-value
	m^2	$W/(m^2 \cdot K)$	-
North	2 477,7	1,03	0,32
North-East	0,0	0,00	0,00
East	0,0	0,00	0,00
South-East	0,0	0,00	0,00
South	0,0	0,00	0,00
South-West	0,0	0,00	0,00
West	0,0	0,00	0,00
North-West	0,0	0,00	0,00
Skylight windows	0,0	0,00	0,00
	2 477,7		

Ventilation system	Air flow rate supply/exhaust		System SFP value	HRU temp. efficiency	Freezing prevention
	$(m^3/s)/(m^3/s)$		$kW/(m^3/s)$	-	°C
separate exhausts	6,3	6,3	0,5	53	-20
air wells	0,7	0,7	1,7	53	-20
Night ventilation	3,2	3,2	1,7	53	-20
TK31	5,8	5,8	1,7	53	-20
TK32	3,0	3,0	1,7	53	-20
TK33	4,5	4,5	1,7	53	-20
TK34	4,3	4,3	1,7	53	-20
TK35	5,2	5,2	1,7	53	-20
TK36 ja 38	4,5	4,5	1,7	53	-20
TK37	0,4	0,4	2,1	53	-20
TK39	2,4	2,4	1,7	53	-20
TK40	2,8	2,8	1,7	53	-20
TK41	1,2	1,2	2,1	53	-20
TK42	0,3	0,3	2,1	53	-20
TK43	0,1	0,1	1,7	53	-20
TK44	0,2	0,2	2,1	53	-20
Ventilation system	45,0	45,0	1,6		

Domestic hot water usage	$m^3/(m^2 \cdot a)$	total m^3/a
	0,103	2217

Internal thermal loads	Occupants	Equipment	Lighting	Utilization rate
	W/m^2	W/m^2	W/m^2	-
	5	12	12	0,65

	E-VALUE CALCULATION **AC SYSTEM ZONE SUMMARY**		
Diplomityöt	Document No.		
	Project No.	H07705.P002	
Diplomityö EPi		Date	Created/checked by
	Latest revision		
	Created	5.8.2013	EPi

AC system zone	Area	Air flow rate		Total dP		otal efficiency		Fan power		Fan dT		Supply air T		Heat recovery unit Efficiency 1)	2)	Sup./exh.	imitation	AC system schedule
		min	max	sup.	exh.	sup.	exh.	sup.	exh.	sup.	exh.	min	max	sizing	energy	relation	temp.	
	m^2	m^3/s	m^3/s	Pa	Pa	%	%	kW	kW	°C	°C	°C	°C	%	%		°C	
erillispoistot	3154,0	6,308	6,308	1	300	100	60	0,006	3,154	0,0	0,0	17,0	19,0	53	66	1,00	-20	IV:(D3) Toimistorakennus
IV-kuilut yms.	363,7	0,727	0,727	700	400	65	60	0,783	0,485	1,0	0,0	17,0	19,0	53	74	1,00	-20	IV:(D3) Toimistorakennus
Night ventilation	0,3	3,228	3,228	700	400	65	60	3,476	2,152	1,0	0,0	17,0	19,0	53	64	1,00	-20	IV: mo-fri 19-06 100 %, sa-su 100%
TK31	2923,6	5,847	5,847	700	400	65	60	6,297	3,898	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK32	1491,9	2,984	2,984	700	400	65	60	3,213	1,989	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK33	2232,7	4,465	4,465	700	400	65	60	4,809	2,977	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK34	2167,7	4,335	4,335	700	400	65	60	4,669	2,890	1,0	0,0	17,0	19,0	53	68	1,00	-20	IV:(D3) Toimistorakennus
TK35	2586,5	5,173	5,173	700	400	65	60	5,571	3,449	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK36 ja 38	2239,1	4,478	4,478	700	400	65	60	4,823	2,985	1,0	0,0	17,0	19,0	53	66	1,00	-20	IV:(D3) Toimistorakennus
TK37	220,0	0,440	0,440	800	500	65	60	0,542	0,367	1,0	0,0	18,0	19,0	53	65	1,00	-20	IV:(D3) Toimistorakennus
TK39	1197,5	2,395	2,395	700	400	65	60	2,579	1,597	1,0	0,0	17,0	19,0	53	65	1,00	-20	IV:(D3) Toimistorakennus
TK40	1379,2	2,758	2,758	700	400	65	60	2,971	1,839	1,0	0,0	17,0	19,0	53	65	1,00	-20	IV:(D3) Toimistorakennus
TK41	597,5	1,195	1,195	800	500	65	60	1,471	0,996	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK42	171,9	0,344	0,344	800	500	65	60	0,423	0,286	1,0	0,0	17,0	19,0	53	67	1,00	-20	IV:(D3) Toimistorakennus
TK43	56,5	0,113	0,113	700	400	65	60	0,122	0,075	1,0	0,0	17,0	19,0	53	65	1,00	-20	IV:(D3) Toimistorakennus
TK44	115,3	0,231	0,231	800	500	65	60	0,284	0,192	1,0	0,0	17,0	19,0	53	65	1,00	-20	IV:(D3) Toimistorakennus

1) User defined efficiency in design conditions.
2) Simulated energy efficiency (=how much heating coil energy of the AC system is saved).

Night ventilation schedule
V = night ventilation
C = night cooling

E-VALUE CALCULATION RESULTS

Created 12.7.2013 EPi

Building type	Office building			
Heated net area	21 520,0	m^2		
E-value	163,1	kWh/(m^2,a) (kWh per heated building net area)		

E-value details	Purchased ene.	Primary energy factor	Primary energy factor weighted energy	
	kWh/a	-	kWh/a	kWh/(m^2·a)
Electricity	1 159 114	1,70	1 970 495	92
District heating	2 138 688	0,70	1 497 081	70
District cooling	107 197	0,40	42 879	2
Renewable fuel	0	0,50	0	0
Fossil fuel	0	1,00	0	0
			0	0
Total	3 404 999	4,3	3 510 455	163

Renewable energy	kWh/a	kWh/(m^2·a)
Solar electricity	0	0
Solar heat	0	0
Wind electricity	0	0
Heat source heat energy taken by the heat pump	0	0

Energy net need	kWh/a	kWh/(m^2·a)
Space heating[2]	1 036 054	48,1
Supply air heating[3]	889 249	41,3
Domestic hot water	149 224	6,9
Cooling	107 197	5,0

[2]includes heating of infiltration air, replacement air and supply air in space
[3]calculated with heat recovery

Thermal loads	kWh/a	kWh/(m^2·a)
Sun	143 726	6,7
Occupants	191 475	8,9
Equipment	459 961	21,4
Lighting	385 574	17,9

	E-VALUE **PURCHASED ENERGY NEED**
Diplomityöt Diplomityö EPi	Document No. Project No. H07705.P002 Date Created/checked by Latest revision Created 12.7.2013 EPi

BASIC INFORMATION:

Building net area: 21 520,0 m²

Building volume: 75 574,0 m³

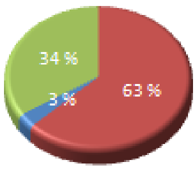
Description of the simulation:

E-Value

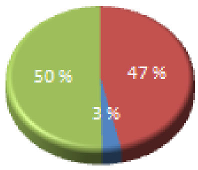
ANNUAL PURCHASED ENERGY NEED

	MWh	kWh/m²	kWh/m³	Energy price EUR/MWh	Energy price EUR	Basic charge EUR	Total EUR
Heating energy	2 138,7	99,4	28,3	45,00	96 240,94	0,00	96 240,94
Cooling energy	107,2	5,0	1,4	63,00	6 753,43	0,00	6 753,43
Electric energy	1 159,1	53,9	15,3	90,00	104 320,30	0,00	104 320,30
Total	**3 405,0**	**158,2**	**45,1**	**198,00**	**207 314,66**	**0,00**	**207 314,66**

ENERGY



COST



E-VALUE

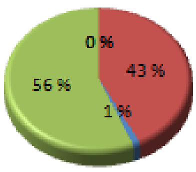
Primary energy	Purchased energy MWh	Primary energy factor	Primary energy factor weighted energy MWh	kWh/m²
Kaukolämpö	2 138,7	0,70	1 497,1	69,6
Kaukojäähdytys	107,2	0,40	42,9	2,0
Sähkö	1 159,1	1,70	1 970,5	91,6
Uusiutuva	0,0	0,50	0,0	0,0
Fossiilinen	0,0	1,00	0,0	0,0
E-value				**163,1**

PRIMARY ENERGY TYPES

Primary energy	Energy cost EUR/MWh	Basic charge EUR
Kaukolämpö	45,00	0,00
Kaukojäähdytys	63,00	0,00
Sähkö	90,00	0,00

On-site renewable energy	MWh	kWh/m²
Solar heat	0,0	0,0
Solar electricity	0,0	0,0
Wind electricity	0,0	0,0
Ground heat	0,0	0,0
Other	0,0	0,0
On-site renewable energy total:	**0,0**	**0,0**

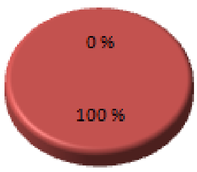
PRIMARY ENERGY FACTOR WEIGHTED ENERGY



ON-SITE RENEWABLE ENERGY, DISTRIBUTION

0 %

ON-SITE RENEWABLE ENERGY SHARE OF TOTAL ENERGY NEED



CASE TENANT

AC SYSTEM ZONE SUMMARY

Diplomityöt

Diplomityö EPi

Document No.			
Project No.	H07705.P002		
	Date	Created/checked by	
Latest revision			
Created	5.8.2013	EPi	

1) User defined efficiency in design conditions.

2) Simulated energy efficiency (=how much heating coil energy of the AC system is saved).

AC system zone	Area	Air flow rate		Total dP		Total efficiency		Fan power		Fan dT	
		min	max	sup.	exh.	sup.	exh.	sup.	exh.	sup.	exh.
	m²	m³/s	m³/s	Pa	Pa	%	%	kW	kW	°C	°C
erillispoistot	81,2	0,378	0,378	1	300	100	60	0,000	0,189	0,0	0,0
TK31	481,5	0,873	0,873	700	400	65	60	0,940	0,582	1,0	0,0
TK32	236,6	0,394	0,394	700	400	65	60	0,424	0,262	1,0	0,0
TK33	395,3	0,906	0,906	700	400	65	60	0,976	0,604	1,0	0,0
TK34	292,9	0,512	0,512	700	400	65	60	0,552	0,342	1,0	0,0
TK35	496,7	0,936	0,936	700	400	65	60	1,008	0,624	1,0	0,0
TK36 ja 38	227,1	0,669	0,669	700	400	65	60	0,721	0,446	1,0	0,0
TK39	179,2	0,179	0,179	700	400	65	60	0,193	0,119	1,0	0,0

AC system zone	Supply air T		Heat recovery unit: Efficiency 1)	Heat recovery unit: Efficiency 2)	Sup./exh.	Limitation	AC system schedule	Night ventilation schedule
	min	max	sizing	energy	relation	temp.		V = night ventilation
	°C	°C	%	%		°C		C = night cooling
erillispoistot	17,0	19,0	0	0	1,00	-20	IV: ma-su 07-21	
TK31	17,0	19,0	70	87	1,00	-20	IV: ma-pe 06-18	(V) YÖT: ma-pe 18-06
TK32	17,0	19,0	70	84	1,00	-20	IV: ma-pe 05-18	(V) YÖT: ma-pe 18-05
TK33	17,0	19,0	70	86	1,00	-20	IV: ma-pe 06-18	(V) YÖT: ma-pe 18-06
TK34	17,0	19,0	50	61	1,00	-5	IV: ma-pe 06-18	(V) YÖT: ma-pe 18-06
TK35	17,0	19,0	70	85	1,00	-20	IV: ma-pe 03-22	(V) YÖT: ma-pe 22-03
TK36 ja 38	17,0	19,0	70	84	1,00	-20	IV: ma-pe 06-18	(V) YÖT: ma-pe 18-06
TK39	17,0	19,0	70	84	1,00	-20	IV: ma-pe 06-18	

RIUSKA	**CASE TENANT** **ENERGY NEED (NET ENERGY)**
Diplomityöt Diplomityö EPi	Document No. Project No. H07705.P002 Date Created/checked by Latest revision Created 5.8.2013 EPi

BASIC INFORMATION:

Geometry model area: 2 390,7 m²

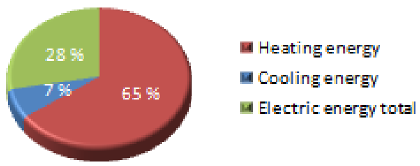
Geometry model volume: 6 817,4 m³

Description of the simulation:

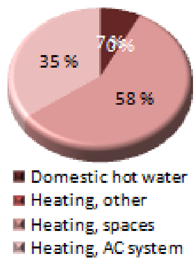
Case tenant

ANNUAL ENERGY NEED

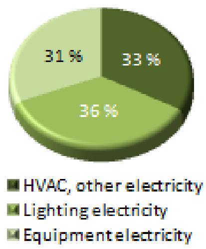
	MWh	kWh/m²	kWh/m³
Heating energy	223	93,2	32,7
Cooling energy	24	9,9	3,5
Electric energy total	95	39,9	14,0
-HVAC, other electricity	31	13,2	4,6
-Lighting electricity	34	14,3	5,0
-Equipment electricity	30	12,4	4,4



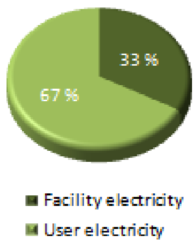
Heating energy



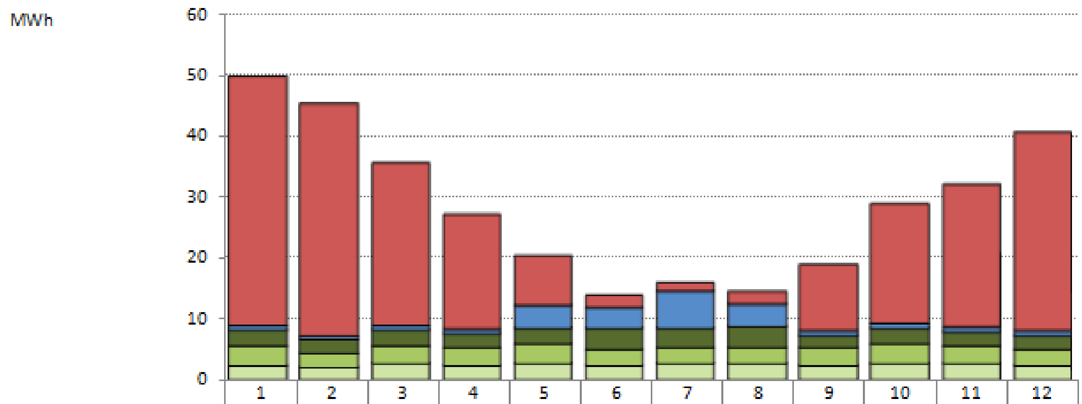
Electricity



Facility and user electricity



MONTHLY ENERGY NEED



	1	2	3	4	5	6	7	8	9	10	11	12
Heating energy	41	38	27	18	8	2	2	2	11	20	23	32
Cooling energy	1	1	1	1	4	3	6	4	1	1	1	1
HVAC, other electricity	3	2	2	2	3	3	3	3	2	3	2	2
Lighting electricity	3	2	3	3	3	2	3	3	3	3	3	3
Equipment electricity	2	2	3	2	3	2	3	3	2	3	3	2

APPENDIX 3: SURVEY QUESTIONS

1. Organisaationne henkilömäärä

- Alle 20
- 20-50
- 51-250
- 251-500
- 501-1000
- yli 1000

2. Organisaationne toimiala

- Media/viihde
- Internet/tietotekniikka/tietoliikenne
- Koulutus/aatteellinen
- Tekstiiliteollisuus
- Markkinointi/markkinointitutkimus
- Hallinto
- Energiateollisuus
- Maatalous/ravintola-ala/elintarviketeollisuus
- Autoteollisuus
- Matkailuala
- Rahoitus/pankki
- Laki
- Lääketiede/lääketeollisuus/hoitoala
- Rakennusala/kehitys/teollinen muotoilu
- Merenkulkuala/kuljetusala
- Muu

3. Asemanne organisaatiossa

- Työntekijä
- Asiantuntija
- Esimies
- Ylin johto

10. Ovatko energiatehokkuus- ja säästöasiat tulleet esille keskusteluissa vuokranantajan kanssa? Millä tavoin?

- [ ] Eivät ole tulleet esille
- [ ] Kulutusraportointi
- [ ] Investoinnit
- [ ] Yhteiset projektit
- [ ] Energiankäyttöön liittyvät tapaamiset
- [ ] Vuokrasopimuksen sisältö

Muu (täsmennä)

6. Onko organisaationne tehnyt energiatehokkuussuunnitelman?

Energiatehokkuussopimuksilla tavoitellaan päästökaupan ulkopuolella olevissa kohderyhmissä energiapalveludirektiivin mukaisesti 9 % suuruista energiansäästöä vuoteen 2016 mennessä. Tavoite lasketaan vuosien 2001–2005 keskimääräisestä energiankäytöstä. Sopimustoiminnan osapuolia ovat ministeriöt, toimialaliitot sekä yritykset ja yhteisöt.

- Kyllä
- Ei

7. Onko organisaatiollanne kestävään kehitykseen ja energiansäästöön liittyviä tavoitteita?

- Kyllä
- Ei

8. Jos organisaatiollanne on kestävään kehitykseen ja energiansäästöön liittyviä tavoitteita, mitä asioita tavoitteet koskevat?

- Hiilidioksidipäästöt
- Energiatehokkuus
- Kiinteistöjen energiankulutus (lämpö, sähkö, vesi)
- Tilatehokkuus
- Jätteiden määrä
- Liikkuminen (työasia-, virka- ja työmatkat)

Muu (täsmennä)

9. Onko kiinteistössänne tehty toimenpiteitä energiatehokkuuden parantamiseksi? Minkälaisia?

- [ ] Ei ole tehty toimenpiteitä
- [ ] Kulutustietojen seuranta ja raportointi
- [ ] Käyttäjien informointi ja opastus
- [ ] Energiatehokkaiden laitteiden hankkiminen
- [ ] Toimistolaitteiden virransäästötilojen käyttöönotto
- [ ] Talotekniikan käyttöaikojen (ilmanvaihto, valaistus) muuttaminen
- [ ] Mittaroinnin lisääminen
- [ ] Korjaukset ja muutostyöt

Muu (täsmennä)

10. Ovatko energiatehokkuus- ja säästöasiat tulleet esille keskusteluissa vuokranantajan kanssa? Millä tavoin?

- [ ] Eivät ole tulleet esille
- [ ] Kulutusraportointi
- [ ] Investoinnit
- [ ] Yhteiset projektit
- [ ] Energiankäyttöön liittyvät tapaamiset
- [ ] Vuokrasopimuksen sisältö

Muu (täsmennä)

11. WWF:n Green Office on toimistoille tarkoitettu ympäristöjärjestelmä. Sen avulla työpaikat voivat vähentää ympäristökuormitustaan, saavuttaa säästöjä ja hidastaa ilmastonmuutosta

Kuuluuko organisaationne WWF:n Green Officeen?

- Kyllä
- Ei

12. Onko organisaationne suunnitelmissa Green Office toimintamallin käyttöönotto?

- Kyllä
- Ei
- En osaa sanoa

13. Onko kiinteistöllä, jossa organisaationne toimii, jokin ympäristöluokitus?

- Ei
- En osaa sanoa
- LEED
- BREEAM
- PROMISE
- Muu (täsmennä)

14. Onko rakennuksen energiatodistus tuttu käsite?

- ○ Kyllä
- ○ Ei

15. Energiatodistus on työkalu rakennusten energiatehokkuuden vertailuun ja parantamiseen myynti- ja vuokraustilanteessa. Energiatodistuksessa esitetään energialuokitus (A-G), joka perustuu rakennuksen E-lukuun. E-luku koostuu rakennuksen laskennallisesta vuotuisesta ostoenergiankulutuksesta painotettuna eri energiamuotojen kertoimilla. Energiatodistus sisältää myös ammattilaisten laatimia säästösuosituksia, joiden avulla voi parantaa energiatehokkuutta.

Arvioi asteikolla 1-5 kuinka suuri merkitys kiinteistönne energiatodistuksella on vuokralaiselle?

1 = ei ollenkaan merkitystä
5 = erittäin suuri merkitys

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

16. Arvioi asteikolla 1-5 kuinka suuri merkitys energiatodistuksella on uusien tilojen valintaperusteelle ja kiinnostavuudelle?

1 = ei ollenkaan merkitystä
5 = erittäin suuri merkitys

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

17. Miten energiatodistus voisi palvella paremmin vuokralaista?

18. Onko ympäristötehokkuutta edistävä vuokrasopimusmalli Green Lease teille tuttu?

- Kyllä
- Ei

19. Käyttääkö organisaationne Green Lease vuokrasopimusmallia?

- Kyllä
- Ei
- En tiedä

20. Haluaisitteko että käyttäytymisenne vaikuttaisi vuokran muodostumiseen?

- Kyllä
- Ei

Voitte perustella vastauksenne halutessanne.

21. Green Leasessa tilojen omistajaa ja vuokraajaa ohjataan taloudellisin kannustimin ympäristötehokkaiden ratkaisuiden hyödyntämiseen. Green Leasessa vuokra muodostuu kiinteästä osuudesta ja ylläpitovuokran liikkuvista osista (sähkö,vesi,lämpö ja jätteet), joihin voidaan vaikuttaa. Hyöty jaetaan omistajan ja vuokralaisen kesken.

Voisiko organisaationne olla kiinnostunut käyttämään Green Lease vuokrasopimusmallia lähitulevaisuudessa?

- Kyllä
- Ei

Voitte perustella vastauksenne halutessanne.

22. Mitä riskejä koette Green Lease vuokrasopimusmallissa olevan?

- [ ] Tilakohtaisten energiankulutustietojen saatavuus/luotettavuus (monivuokralaisrakennus)
- [ ] Sisäilmasto-olosuhteet kärsivät
- [ ] Lisää byrokratiaa ja työtä
- [ ] Vuokra nousee, koska käyttäjät eivät välitä energiankulutuksestaan

Muu (täsmennä)

23. Oletteko tyytyväisiä tämän hetkisiin olosuhteisiin tiloissanne?

- ( ) Kyllä
- ( ) Ei

24. Jos ette ole tyytyväisiä olosuhteisiin, niin minkälaisia ongelmia olette havainneet?

- [ ] Lämpötila vaihtelee eri puolilla rakennusta
- [ ] Vedontunne
- [ ] Tunkkainen ilma
- [ ] Huono valaistus

Muu (täsmennä)

25. Kumpi miellyttää teitä enemmän?

- ( ) Käyttäjä voi säätää olosuhteisiin vaikuttavia suureita kuten lämpötilaa ja valaistusta
- ( ) Automatisointi hoitaa säädöt käyttäjän puolesta

Voit perustella vastauksenne halutessanne.

26. Miten tilojenne energiankulutusta mittaroidaan?

	Mittaroitava alue
Sähkö	
Lämmitys	
Jäähdytys	
Vesi	

27. Miten tilojenne energiankulutuksesta raportoidaan?

	Aikaväli	Peruste
Sähkö		
Lämmitys		
Jäähdytys		
Vesi		
Jätteiden määrä		
Hiilidioksidipäästöt		

28. Minkälaiset energiankulutukseen liittyvät suureet kiinnostavat?

- ☐ Energiankulutuksen vertaus muihin vastaaviin organisaatioihin
- ☐ Kerroskohtaiset erot
- ☐ Sisäilmanlaatu
- ☐ Käyttäytymisen vaikutus (valaistus,laitteet)
- ☐ Hiilijalanjälki

Muu (täsmennä)

29. Minkälainen mittari kuvaa parhaiten kiinteistön energiatehokkuutta?

- ○ kWh/m2
- ○ kWh/hlö
- ○ €/m2
- ○ kWh/työpiste
- ○ kg CO2e/m2
- ○ Muu (täsmennä)

30. Minkälaiset energiatehokkuuspalvelut kiinnostaisivat ja olisivat hyödyksi?